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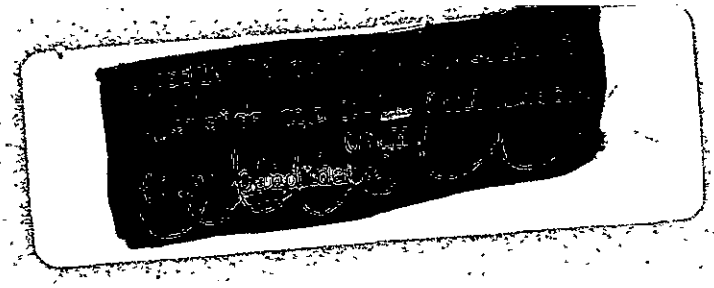

BONE DENSITY STUDIES OF BED REST SUBJECTS AT THE PUBLIC HEALTH SERVICE HOSPITAL IN SAN FRANCISCO, BY THE TEXAS WOMAN'S UNIVERSITY RADIOGRAPHIC METHOD

Under the Sponsorship of the

National Aeronautics and Space Administration

Contract No. NAS 9-9427

Final Report

TEXAS WOMAN'S UNIVERSITY
DENTON, TEXAS

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The Director of the Texas Woman's University Research Institute and an Assistant travelled to San Francisco once a month for the purpose of measuring changes in bone density in subjects who were participating in a bed rest-phosphate study at the U. S. Public Health Hospital in that city. The radiographic bone density method developed by staff members of the Texas Woman's University Research Institute was used in this study. Bill J. Stover, X-Ray Technologist, and Walter W. Gilchrist, Research Associate, alternated in accompanying the Director of the T.W.U. Research Institute for the purpose of taking the x-rays during each trip.

The first trip on this contract was made on January 31, 1969, with x-rays taken on the early morning of February 1, using a selected x-ray machine at the Hospital, together with special x-ray films which they took with them from T.W.U. The left foot in lateral aspect and the left hand in

anterior-posterior position were x-rayed in the same positions and with the same exposure energy (167 milliroentgens) as in the case of the astronauts.

The subjects x-rayed on this first trip included the following:

1. Randall Robinson;
2. Alfred Diaz;
3. Fred Bratcher;
4. Fred Kolb; and
5. George McNiel.

The left hand of George McNiel had been amputated, and hence his right hand was used for his series of x-rays.

When we returned to our own laboratories, analyses of the films began. The analysis of each set of films for one subject included the following:

(a). Two preliminary scans on the foot, one of the central section of the os calcis and one of the central section of the talus. See Appendix of this Report if you are not familiar with the T.W.U. method of taking and developing x-rays.

(b). Multiple sections of the os calcis, consisting of scans 1 millimeter apart, covering approximately 60 per cent of the os calcis or large heel bone, where there is no

overlapping of other bones. Usually 41-44 scans are required to cover this area of the heel bone in a mature man, depending on the size of the foot.

(c). The following sections of the hand and wrist are scanned--

(1) Hand phalanx 5/2 (about 17-19 sections scanned);

(2) Hand phalanx 4/2 (about 24-28 sections are scanned);

(3) One scan across the capitate, a wrist carpal; and

(4) One scan each across the distal ends of the radius and of the ulna.

Therefore, from 87 to 96 sections in the hand and foot are measured for bone density in an adult male, giving results for the various types of bone from lacy trabecular to dense cortical skeletal tissue.

See Appendix for illustrations of the sections which are scanned on the radiographs of the hand and foot of this study.

Second Trip on this Project

During the second monthly trip on the U. S. Public Health Hospital project in San Francisco, we went to San Francisco on March 27, 1969. Radiographs were taken on the early morning of March 28th. An early hour (between 6:30 and 7:00 A.M.) was selected for taking this series of x-rays

so that the x-ray machine which we had selected for our precise work would not be tied up after the busy day at the hospital had begun.

The same men were radiographed which had been included during the first test, including a new man named Bly who appeared for x-rays who did not continue past this date. Upon our return to the T.W.U. Laboratories, after each trip, work on the development and evaluation of the films is carried out. The x-ray films, which are a special type, could not be developed at the Hospital, which has an automatic development system which causes the emulsion on the films to be scratched. Moreover, the temperature of the processing solutions must be precisely standardized, as well as the timing.

Third Trip on this Project

The third trip for obtaining radiographs for this study occurred on May 6th to 9th, 1970, and the fourth was made on June 2nd and 3rd, 1970. The same men were radiographed as in the earlier reports.

Using the central os calcis section as a preliminary method of finding changes in bone mass of the heel bone, since this represents a very sensitive part of the trabecular tissue in this part of the skeletal anatomy, changes were investigated in the five men who had taken part in the study to this point.

FIRST GROUP OF SUBJECTS

Changes in Multiple Sections of the Os Calcis in Terms of Integrator Counts during the First Bed Rest Phase of the Project, with and without Exercise

Tables I and II which follow give the data on multiple sections of the os calcis during bed rest without exercise for the two men who carried on through this phase of the project. This part of the project was effectuated during the period from January 27 to April 21, 1970, with the x-rays taken on February 1 (A), March 28 (B), and again through May 7 (C) representing this time as nearly as possible.

During the first 12 weeks of the study, two of the men, Robinson and Kolb, remained in bed with limited activity. The other three, Bratcher, Diaz, and McNeil, on the other hand, exercised while lying down, using an Exer-Genie.

The radiographs made during this period were those taken on 2/1/69 3/28/69, and 5/7/69. The radiographs made on 6/3/69 were those which followed the bed rest period by Robinson and Kolb, but which were made after these two men had begun a phase of the study during which phosphate was used as a daily dietary supplement. This second part of the investigation extended from April 21 through July 14.

TABLE 1

CHANGES IN MULTIPLE SECTIONS OF THE OS CALCIS IN TERMS OF

DURING THE BED REST PHASE OF THE PROJECT

SUBJECT: RANDALL ROBINSON

Position of Section	Regular Tracing A 2/1/69	Regular Tracing B 3/28/69	Regular Tracing C 5/7/69	Regular Tracing D 6/3/69	Regular Tracing E 7/14/69	Regular Tracing F 8/8/69	Regular Tracing G 9/15/69	Regular Tracing H 10/1
2 mm up	10459	9913	10060	9693	10617	9494	9107	9
1 mm up	10666	10048	10157	9736	10837	9467	9246	9
CONVENTIONAL TRACE	10646	10010	10104	9659	10891	9512	9233	9
1 mm down	10217	9634	9783	9149	10191	9042	8691	9
2 mm down	10016	9567	9539	8971	10040	8925	8636	9
3 mm down	9894	9463	9418	8930	9873	8652	8482	9
4 mm down	9793	9352	9342	8838	9809	8693	8399	9
5 mm down	9687	9181	9184	8695	9669	8502	8239	8
6 mm down	9558	9107	9101	8544	9613	8436	8068	8
7 mm down	9458	8869	8954	8467	9412	8229	7945	8
8 mm down	9350	8807	8936	8335	9347	8201	7843	8
9 mm down	9087	8674	8754	8229	9159	7975	7692	8
10 mm down	8982	8582	8626	8097	9004	7931	7618	8
11 mm down	8831	8437	8436	7914	8785	7801	7405	8
12 mm down	8601	8189	8275	7722	8548	7466	7165	7
13 mm down	8405	7944	8060	7484	8291	7297	6994	7
14 mm down	8169	7691	7777	7298	8016	7039	6736	7
15 mm down	7856	7414	7525	7018	7602	6754	6497	6
16 mm down	7427	6995	7152	6609	7357	6526	6028	6
17 mm down	7199	6780	6846	6426	7073	6163	5861	6
18 mm down	6991	6565	6601	6161	6812	5985	5641	6
19 mm down	6726	6384	6363	5983	6626	5757	5432	5
20 mm down	6458	6116	6130	5777	6299	5524	5229	5
21 mm down	6368	5965	5885	5543	6157	5308	5049	5
22 mm down	6253	5840	5735	5442	6009	5129	4990	5
23 mm down	6064	5672	5576	5256	5843	5034	4845	5
24 mm down	5944	5495	5402	5139	5707	4866	4706	5
25 mm down	5804	5376	5297	4999	5669	4818	4643	4
26 mm down	5736	5301	5176	4989	5617	4700	4536	4
27 mm down	5713	5208	5134	4933	5593	4681	4619	4
28 mm down	5624	5109	5016	4911	5598	4681	4630	4
29 mm down	5428	5057	4922	4729	5449	4616	4484	4
30 mm down	5313	4881	4885	4672	5334	4548	4370	4
31 mm down	5203	4837	4638	4537	5184	4463	4284	4
32 mm down	5118	4661	4607	4457	5140	4357	4260	4
33 mm down	4943	4550	4561	4385	4972	4176	4204	4
34 mm down	4748	4341	4472	4205	4756	4004	4000	4
35 mm down	4367	4052	3957	3932	4418	3732	3653	3
36 mm down	3886	3545	3427	3600	3861	3463	3288	3
37 mm down	3342	2970	3001	3042	3235	2906	2867	2
38 mm down	2537	2350	2335	2353	2446	2275	2294	2
Total	296,877	278,932	279,149	264,859	294,859	257,128	247,919	265,8

TABLE I

MULTIPLE SECTIONS OF THE OS CALCIS IN TERMS OF INTEGRATOR COUNTS

DURING THE BED REST PHASE OF THE PROJECT

gular acing C 7/7/69	Regular Tracing D 6/3/69	Regular Tracing E 7/14/69	Regular Tracing F 8/8/69	Regular Tracing G 9/15/69	Regular Tracing H 10/14/69	Per Cent Change Between Tests			
						A to C	C to E	E to F	F to H
0060	9693	10617	9494	9107	9807	-3.81	+5.54	-10.58	+3.30
0157	9736	10837	9467	9246	9971	-4.77	+6.69	-12.64	+5.32
010	9659	10891	9512	9233	9978	-5.09	+7.79	-12.66	+4.90
9783	9149	10191	9042	8691	9407	-4.25	+4.17	-11.27	+4.04
9539	8971	10040	8925	8636	9241	-4.76	+5.25	-11.10	+3.54
9418	8930	9873	8652	8482	9050	-4.81	+4.83	-12.37	+4.60
9342	8838	9809	8693	8399	9019	-4.61	+5.00	-11.38	+3.75
9184	8695	9669	8502	8239	8848	-5.19	+5.28	-12.07	+4.07
9101	8544	9613	8436	8068	8856	-4.78	+5.63	-12.24	+4.98
8954	8467	9412	8229	7945	8616	-5.33	+5.11	-12.57	+4.70
8936	8335	9347	8201	7843	8504	-4.43	+4.60	-12.26	+3.69
8754	8229	9159	7975	7692	8335	-3.66	+4.63	-12.93	+4.51
8626	8097	9004	7931	7618	8258	-3.96	+4.38	-11.92	+4.12
8436	7914	8785	7801	7405	8047	-4.47	+4.14	-11.20	+3.15
8275	7722	8548	7466	7166	7825	-3.79	+3.30	-12.66	+4.81
8060	7484	8291	7297	6994	7628	-4.10	+2.87	-11.99	+4.54
7777	7298	8016	7039	6736	7347	-4.80	+3.07	-12.19	+4.38
7525	7018	7602	6754	6497	6907	-4.21	+1.02	-11.15	+2.27
7152	6609	7357	6526	6028	6724	-3.70	+2.87	-11.30	+3.03
6846	6426	7073	6163	5861	6416	-4.90	+3.32	-12.87	+4.10
6601	6161	6812	5985	5641	6146	-5.58	+3.20	-12.14	+2.69
6363	5983	6626	5757	5432	5940	-5.40	+4.13	-13.12	+3.18
6130	5777	6299	5524	5229	5685	-5.08	+2.76	-12.30	+2.91
5885	5543	6157	5308	5049	5525	-7.58	+4.62	-13.79	+4.09
5735	5442	6009	5129	4999	5304	-8.28	+4.78	-14.64	+3.41
5576	5256	5843	5034	4845	5258	-8.05	+4.79	-13.85	+4.45
5402	5139	5707	4866	4706	5121	-9.12	+5.65	-14.74	+5.24
529	4999	5669	4818	4643	4950	-8.74	+7.02	-15.01	+2.74
5176	4989	5617	4700	4536	4829	-9.76	+8.52	-16.32	+2.74
5134	4933	5593	4681	4619	4831	-10.13	+8.94	-16.31	+3.20
5016	4911	5598	4681	4630	4699	-10.81	+11.60	-16.38	+0.38
4922	4729	5449	4616	4484	4612	-9.49	+10.71	-15.29	-0.09
4885	4672	5334	4548	4370	4593	-8.06	+9.19	-14.74	+0.99
4638	4537	5184	4463	4284	4481	-10.86	+11.77	-13.91	+0.40
4607	4457	5140	4357	4260	4472	-9.98	+11.57	-15.23	+2.64
4561	4385	4972	4176	4204	4270	-7.73	+9.01	-16.01	+2.25
4472	4205	4756	4004	4000	4032	-5.81	+6.35	-15.81	+0.70
3957	3932	4418	3732	3653	3786	-9.39	+11.65	-15.53	+1.45
3427	3600	3861	3463	3288	3376	-11.81	+12.66	-10.31	-2.51
3001	3042	3235	2906	2867	2883	-10.20	+7.80	-10.17	-0.79
2335	2353	2446	2275	2294	2311	-7.96	+4.75	-6.99	+1.58
,149	264,859	294,859	257,128	247,919	265,888	-5.97	+5.63	-12.80	+3.41

TABLE II

CHANGES IN MULTIPLE SECTIONS OF THE OS CALCIS I

COUNTS DURING THE BED REST PHASE OF 3

SUBJECT: FRED KOLB

Position of Section	Regular Tracing A 2/1/69	Regular Tracing B 3/28/69	Regular Tracing C 5/7/69	Regular Tracing D 6/3/69	Regular Tracing E 7/14/69	Regular Tracing F 8/8/69	Re. Tr. 9/
2 mm up	9352	9528	9356	8945	8955	9652	
1 mm up	9366	9567	9362	8850	8930	9632	
CONVENTIONAL TRACE	9383	9333	9102	8982	9063	9621	
1 mm down	9306	9547	9502	9076	9371	9360	
2 mm down	9256	9243	9028	8901	9058	9052	
3 mm down	8767	9132	9056	8939	9018	8980	
4 mm down	8610	8919	8754	8563	8942	8905	
5 mm down	8492	8862	8725	8452	8870	8800	
6 mm down	8466	8715	8613	8364	8730	8644	
7 mm down	8264	8547	8468	8109	8328	8259	
8 mm down	8125	8468	8272	8047	8177	8166	
9 mm down	7894	8299	8084	7993	8281	8244	
10 mm down	7743	8009	7906	7725	8529	7982	
11 mm down	7608	7828	7610	7461	7826	7714	
12 mm down	7524	7643	7399	7246	7300	7216	
13 mm down	7334	7495	7127	7069	7123	7118	
14 mm down	7196	7450	6991	6940	6973	6929	
15 mm down	7039	6999	6942	6773	6824	6761	
16 mm down	6816	6713	6530	6631	6775	6495	
17 mm down	6688	6483	6266	6396	6588	6252	
18 mm down	6614	6351	6085	6056	6443	6097	
19 mm down	6533	6203	5981	5927	6357	5999	
20 mm down	6464	6059	5999	5875	6031	5804	
21 mm down	6314	5808	5857	5799	5967	5617	
22 mm down	6160	5644	5585	5417	5806	5417	
23 mm down	6057	5518	5492	5271	5508	5347	
24 mm down	5935	5379	5315	5044	5398	5023	
25 mm down	5785	5141	5062	4932	5000	4975	
26 mm down	5596	4898	4821	4563	4804	4766	
27 mm down	5370	4718	4658	4445	4574	4499	
28 mm down	5126	4407	4401	4307	4421	4355	
29 mm down	4910	4212	4237	4151	4223	4211	
30 mm down	4757	4015	4043	4075	4177	4108	
31 mm down	4580	3855	3842	3768	3951	3887	
32 mm down	4490	3694	3683	3331	3505	3456	
33 mm down	4398	3649	3610	3171	3544	3395	
34 mm down	4158	3468	3465	3111	3482	3244	
35 mm down	4044	3406	3345	3101	3312	3268	
36 mm down	3791	3224	3202	2953	3226	3149	
37 mm down	3277	2974	2965	2964	2851	2788	
38 mm down	2632	2368	2270	2009	2281	2139	
39 mm down	1910	1572	1641	1565	1645	1585	
Total	272,130	263,343	258,679	251,347	260,167	256,911	261,

TABLE II

N MULTIPLE SECTIONS OF THE OS CALCIS IN TERMS OF INTEGRATOR COUNTS DURING THE BED REST PHASE OF THE PROJECT

Regular Tracing C 5/7/69	Regular Tracing D 6/3/69	Regular Tracing E 7/14/69	Regular Tracing F 8/8/69	Regular Tracing G 9/15/69	Regular Tracing H 10/14/69	Per Cent Change between Tests			
						A to C	C to E	E to F	F to H
9356	8945	8955	9552	9594	9345	+0.04	-4.29	+7.78	-3.18
9362	8860	8930	9632	9629	9447	+0.04	-4.61	+7.86	-1.92
9102	8982	9063	9621	9609	9528	-2.99	-0.43	+6.16	-0.97
9502	9076	9371	9360	9434	9330	+2.11	-1.38	-0.12	-0.32
[illegible]8	8901	9058	9052	9204	9174	-2.46	+0.33	-0.07	+1.35
[illegible]6	8939	9018	8980	9171	9091	+3.41	-0.53	-0.42	+1.24
8754	8563	8942	8905	9048	8889	+1.67	+2.15	-0.41	-0.18
8725	8492	8870	8800	8955	8799	+2.74	+1.66	-0.79	-0.01
8613	8364	8730	8644	8826	8660	+1.80	+1.30	-0.98	+0.18
8468	8109	8328	8259	8658	8581	+2.47	-1.65	-0.83	+3.90
8272	8047	8177	8166	8505	8419	+1.81	-1.15	-0.13	+3.10
8086	7993	8281	8244	8303	8263	+2.43	+2.41	-0.45	+0.23
7906	7725	8529	7982	8035	8170	+2.10	+7.88	-6.41	+2.35
7610	7461	7826	7714	7834	7920	+0.03	+2.84	-1.43	+2.67
7399	7246	7300	7216	7474	7752	-1.66	-1.34	-1.15	+7.43
7127	7069	7123	7118	7333	7504	-2.82	-0.06	-0.07	+5.42
6991	6940	6973	6929	7080	7342	-2.85	-0.26	-0.63	+5.96
6942	6773	6824	6761	6818	7115	-1.38	-1.70	-0.92	+5.24
6530	6631	6775	6495	6570	6970	-4.20	+3.75	-4.13	+7.31
6266	6396	6588	6252	6317	6735	-6.31	+5.14	-5.10	+7.72
6085	6056	6443	6097	6168	6545	-8.00	+5.88	-5.37	+7.35
5981	5927	6357	5999	6062	6482	-8.45	+6.29	-5.63	+8.05
5999	5875	6031	5804	5895	6193	-7.19	+0.53	-3.76	+6.70
5857	5799	5967	5617	5651	5965	-7.24	+1.88	-5.86	+6.20
5585	5417	5806	5417	5435	5804	-9.33	+3.96	-6.70	+7.14
5492	5271	5508	5347	5364	5698	-9.33	+0.29	-2.92	+6.56
5315	5044	5398	5023	5132	5447	-10.45	+1.56	-6.95	+8.44
5062	4932	5000	4975	5036	5359	-12.50	-1.22	-0.50	+7.72
4821	4563	4804	4766	4947	5100	-13.85	-0.35	-0.79	+7.01
[illegible]3	4445	4574	4499	4608	4852	-13.26	-1.80	-1.64	+7.85
[illegible]1	4307	4421	4355	4364	4601	-14.14	+0.45	-1.49	+5.65
4237	4151	4223	4211	4144	4340	-13.71	-0.33	-0.28	+3.06
4048	4075	4177	4108	3914	4092	-14.90	+3.19	-1.65	-0.39
3842	3768	3951	3887	3724	3932	-16.11	+2.84	-1.62	+1.16
3688	3331	3505	3456	3608	3823	-17.86	-4.96	-1.40	+10.62
3610	3171	3544	3395	3609	3744	-17.92	-1.83	-4.20	+10.28
3465	3111	3482	3244	3475	3578	-16.67	+0.49	-6.83	+10.30
3345	3101	3312	3268	3338	3358	-17.28	-0.99	-1.33	+2.75
3202	2953	3226	3149	3193	3241	-15.54	+0.75	-2.39	+2.92
2965	2964	2851	2788	2900	2960	-9.52	-3.84	-2.21	+6.17
2270	2009	2281	2139	2393	2532	-13.75	+0.48	-6.22	+18.37
1641	1565	1645	1585	1769	1739	-14.08	+0.24	-3.65	+9.72
258,679	251,347	260,167	256,911	261,126	266,419	-4.94	+0.58	-1.25	+3.70

The two men who did not have the exercise experience (Robinson and Kolb) showed slight losses in bone density of the central os calcis, -5.97 per cent for the first man and -4.94 per cent for the second, with slight gains in this anatomic site in the three men who underwent daily exercise in bed (Bratcher, +2.33, Diaz, +2.10, and McNeil, +7.10 per cent) during the first 12 weeks of the first bed rest. See Tables III, IV, and V.

Importance of Exercise during Recumbency

Any favorable change from exercise during recumbency may be understood better from the following information.

Trueta, Nuffield Professor Emeritus of Orthopedic Surgery at the University of Oxford, in his classical treatise on Studies of the Development and Decay of the Human Frame[1] has stated: "The ability of the osteoblast (in the bone) to synthesize the required protein for its matrix depends on the availability of amino acids and other constituents needed for the synthesis. It has long been known that immobilization, bed rest, and lack of muscle activity are all factors contributing to osteoporosis, a condition of decreased skeletal mass associated with increased porosity. Why this is so has not yet been fully explained, but that the osteoblast-osteocyte syncytium appears to be adversely affected by lack of activity is unquestionable."

TABLE III

CHANGES IN MULTIPLE SECTIONS OF THE OS CALF

COUNTS DURING THE BED REST PHASE

SUBJECT: FRED BRATCHER

Position of Section	Regular Tracing A 2/1/69	Regular Tracing B 3/28/69	Regular Tracing C 5/7/69	Regular Tracing D 6/3/69	Regular Tracing E 7/14/69	
2 mm up	11141	11906	11471	11171	11150	
1 mm up	11134	11826	11432	11224	11189	
CONVENTIONAL TRACE	11089	11811	11465	12227	12180	
1 mm down	10021	10772	11368	11030	11408	
2 mm down	10788	10751	11068	11039	11026	
3 mm down	10637	10833	10910	10650	10623	
4 mm down	10491	10525	10741	10486	10482	
5 mm down	10466	10597	10673	10383	10258	
6 mm down	10297	10475	10527	10154	10019	
7 mm down	10206	10408	10433	10072	9923	
8 mm down	9948	10024	10174	10065	9963	
9 mm down	9858	9914	10035	9951	9918	
10 mm down	9769	9830	9926	9828	9719	
11 mm down	9582	9555	9634	9568	9478	
12 mm down	9212	9298	9283	9254	9123	
13 mm down	9062	9128	9178	9140	9005	
14 mm down	8611	8683	8631	8616	8790	
15 mm down	7938	7928	8109	8037	8134	
16 mm down	6898	6911	6994	7955	6893	
17 mm down	6374	6426	6457	6413	6426	
18 mm down	5778	5831	5976	5887	5830	
19 mm down	5519	5694	5621	5577	5555	
20 mm down	5004	5124	5137	5071	5061	
21 mm down	4814	4890	4872	4810	4764	
22 mm down	4507	4542	4593	4579	4484	
23 mm down	4250	4313	4336	4301	4252	
24 mm down	4102	4151	4144	4123	4132	
25 mm down	4007	4056	4045	4095	4053	
26 mm down	3852	3898	3909	3887	3825	
27 mm down	3816	3904	3837	3834	3800	
28 mm down	3720	3799	3733	3763	3687	
29 mm down	3523	3526	3561	3519	3503	
30 mm down	3366	3375	3379	3319	3317	
31 mm down	2769	2776	2816	2848	2779	
32 mm down	2182	2183	2196	2175	2169	
Total	254,731	259,963	260,664	259,051	256,918	2

TABLE III

CHANGES IN MULTIPLE SECTIONS OF THE OS CALCIS IN TERMS OF INTEGRATOR COUNTS DURING THE BED REST PHASE OF THE PROJECT

FRED BRATCHER

	Regular Tracing A 2/1/69	Regular Tracing B 3/28/69	Regular Tracing C 5/7/69	Regular Tracing D 6/3/69	Regular Tracing E 7/14/69	Regular Tracing F 8/8/69	Per Cent Change between Tests		
							A to C	C to E	E to F
	11141	11906	11471	11171	11150	11428	+2.96	-2.80	+2.49
	11134	11826	11432	11224	11189	11386	+2.68	-2.12	+1.76
AL									
	11089	11811	11465	12227	12180	12031	+3.39	+6.24	-1.22
n	10021	10772	11368	11030	11408	11782	+3.15	+0.35	+3.28
n	10788	10751	11068	11039	11026	11465	+2.59	-0.38	+3.98
n	10637	10833	10910	10650	10623	10964	+2.57	-2.63	+3.21
n	10491	10525	10741	10486	10482	10874	+2.38	-2.41	+3.74
n	10466	10597	10673	10383	10258	10750	+1.98	-3.89	+4.80
n	10297	10475	10527	10154	10019	10671	+2.23	-4.82	+6.51
n	10206	10408	10433	10072	9923	9997	+2.22	-4.89	+0.74
n	9948	10024	10174	10065	9963	9970	+2.27	-2.07	+0.07
n	9858	9914	10035	9951	9918	9935	+1.80	-1.16	+0.17
n	9769	9830	9926	9828	9719	9885	+1.61	-2.08	+1.71
n	9582	9555	9634	9568	9478	9689	+0.54	-1.62	+2.23
n	9212	9298	9283	9254	9123	9424	+0.77	-1.72	+3.30
n	9062	9128	9178	9140	9005	9213	+1.28	-1.88	+2.31
n	8611	8683	8631	8616	8790	8809	+0.23	+1.84	+0.22
n	7938	7928	8109	8037	8134	8244	+2.15	+0.31	+1.35
n	6898	6911	6994	7955	6893	7141	+1.39	-1.44	+3.60
n	6374	6426	6457	6413	6426	6607	+1.30	-0.48	+2.82
n	5778	5831	5976	5887	5830	5886	+3.43	-2.44	+0.96
n	5519	5694	5621	5577	5555	5664	+1.85	-1.17	+1.96
n	5004	5124	5137	5071	5061	5075	+2.66	-1.48	+0.28
n	4814	4890	4872	4810	4764	4837	+1.20	-2.22	+1.53
n	4507	4542	4593	4579	4484	4665	+1.91	-2.37	+4.04
n	4250	4313	4336	4301	4252	4404	+2.02	-1.94	+3.57
n	4102	4151	4144	4123	4132	4244	+1.02	-0.29	+2.71
n	4007	4056	4045	4095	4053	4198	+0.95	+0.20	+3.58
n	3852	3898	3909	3887	3825	3987	+1.48	-2.15	+4.23
n	3816	3904	3837	3834	3800	3836	+0.55	-0.96	+0.95
n	3720	3799	3733	3763	3687	3772	+0.35	-1.23	+2.30
n	3523	3526	3561	3519	3503	3662	+1.08	-1.63	+4.54
n	3366	3375	3379	3319	3317	3387	+0.39	-1.83	+2.11
n	2769	2776	2816	2848	2779	2819	+1.70	-1.31	+1.44
n	2182	2183	2196	2175	2169	2181	+0.64	-1.23	+0.55
	254,731	259,963	260,664	259,051	256,918	262,882	+2.33	-1.44	+2.32

TABLE IV

CHANGES IN MULTIPLE SECTIONS OF THE OS CALCIS IN T

COUNTS DURING THE BED REST PHASE OF THE

SUBJECT: ALFREDO DIAZ

Position of Section	Regular Tracing A 2/1/69	Regular Tracing B 3/28/69	Regular Tracing C 5/7/69	Regular Tracing D 6/3/69	Regular Tracing E 7/14/69	Regular Tracing F 8/8/6
2 mm up	8218	7678	8198	8074	6543	88
1 mm up	8236	7765	8211	8077	6571	88
CONVENTIONAL TRACE	8210	7735	8219	7979	6546	881
1 mm down	8098	7500	8071	7869	6416	86
2 mm down	7875	7394	7899	7736	6258	83
3 mm down	7515	7053	7541	7346	5961	80
4 mm down	7291	6872	7483	7104	5806	78
5 mm down	7128	6721	7302	6948	5766	77
6 mm down	7027	6605	7252	6840	5639	75
7 mm down	6933	6533	7049	6715	5546	73
8 mm down	6816	6518	6952	6546	5397	71
9 mm down	6684	6366	6778	6391	5347	69
10 mm down	6508	6221	6688	6246	5122	67
11 mm down	6314	5994	6416	6006	4991	64
12 mm down	6005	5763	6204	5731	4708	61
13 mm down	5737	5491	5806	5459	4616	57
14 mm down	5438	5209	5501	5087	4345	54
15 mm down	5212	4956	5350	4854	4101	51
16 mm down	4907	4754	5137	4614	3956	49
17 mm down	4669	4590	4912	4363	3769	46
18 mm down	4578	4430	4712	4164	3632	43
19 mm down	4427	4300	4561	3903	3554	42
20 mm down	4248	4144	4373	3765	3428	40
21 mm down	4103	3944	4213	3606	3299	38
22 mm down	3966	3839	4030	3419	3154	37
23 mm down	3866	3775	3957	3316	3091	35
24 mm down	3759	3655	3858	3252	3021	34
25 mm down	3651	3576	3737	3106	2931	33
26 mm down	3516	3541	3640	3014	2908	32
27 mm down	3423	3427	3557	2942	2788	30
28 mm down	3366	3358	3492	2835	2718	30
29 mm down	3264	3282	3370	2767	2662	29
30 mm down	3193	3206	3252	2686	2595	28
31 mm down	3082	3058	3167	2652	2516	27
32 mm down	2852	2814	2938	2438	2242	25
33 mm down	2513	2493	2667	2121	2087	23
34 mm down	1855	2068	2069	1591	1609	17
Total	194,483	186,628	198,562	181,557	155,539	196,5

TABLE IV.

CHANGES IN MULTIPLE SECTIONS OF THE OS CALCIS IN TERMS OF INTEGRATOR COUNTS DURING THE BED REST PHASE OF THE PROJECT

REDO DIAZ

Regular Tracing A 2/1/69	Regular Tracing B 3/28/69	Regular Tracing C 5/7/69	Regular Tracing D 6/3/69	Regular Tracing E 7/14/69	Regular Tracing F 8/8/69	Per Cent Change between Tests		
						A to C	C to E	E to F
8218	7678	8198	8074	6543	8848	-0.24	-20.19	+35.23
8236	7765	8211	8077	6571	8867	-0.30	-19.97	+34.94
8210	7735	8219	7979	6546	8819	+0.11	-20.36	+34.72
[illegible]98	7500	8071	7869	6416	8610	-0.33	-20.50	+34.20
[illegible]875	7394	7899	7736	6258	8363	+0.30	-20.77	+33.64
7515	7053	7541	7346	5961	8092	+0.34	-20.95	+35.75
7291	6872	7483	7104	5806	7843	+2.63	-22.41	+35.08
7128	6721	7302	6948	5766	7735	+2.44	-21.03	+34.15
7027	6605	7252	6840	5639	7541	+3.20	-22.24	+33.73
6933	6533	7049	6715	5546	7373	+1.67	-21.32	+32.94
6816	6518	6952	6546	5397	7171	+2.00	-22.37	+32.87
6684	6366	6778	6391	5347	6956	+1.41	-22.59	+32.57
6508	6221	6688	6246	5122	6758	+2.77	-23.41	+31.94
6314	5994	6416	6006	4991	6481	+1.62	-22.21	+29.85
6005	5763	6204	5731	4708	6160	+3.31	-24.11	+30.84
5727	5491	5806	5459	4616	5780	+1.20	-20.50	+25.22
5438	5209	5501	5087	4345	5490	+1.16	-21.01	+26.35
5212	4956	5350	4854	4101	5117	+2.65	-23.34	+24.77
4907	4754	5137	4614	3956	4921	+4.69	-22.99	+24.39
4669	4590	4912	4363	3769	4635	+5.20	-23.27	+34.56
4578	4430	4712	4164	3632	4365	+2.93	-22.92	+20.18
4427	4300	4561	3903	3554	4237	+3.03	-22.08	+19.22
4248	4144	4373	3765	3428	4069	+2.94	-21.61	+15.78
4103	3944	4213	3606	3299	3830	+2.68	-21.69	+16.10
3966	3839	4030	3419	3154	3712	+1.61	-21.74	+17.69
3866	3775	3957	3316	3091	3555	+2.35	-21.88	+15.01
3759	3655	3858	3252	3021	3460	+2.63	-21.69	+14.53
[illegible]651	3576	3737	3106	2931	3311	+2.36	-21.57	+12.96
[illegible]16	3541	3640	3014	2908	3203	+3.53	-20.11	+32.03
[illegible]423	3427	3557	2942	2788	3065	+3.91	-21.62	+9.94
3366	3358	3492	2835	2718	3021	+3.74	-22.16	+11.15
3264	3282	3370	2767	2662	2946	+3.25	-21.01	+10.67
3193	3206	3252	2686	2595	2832	+1.85	-20.20	+9.13
3082	3058	3167	2652	2516	2735	+2.76	-20.55	+8.70
2852	2814	2938	2438	2242	2521	+3.02	-23.69	+12.44
2513	2493	2667	2121	2087	2251	+6.13	-21.93	+7.86
1855	2068	2069	1591	1609	1823	+11.54	-22.23	+13.86
194,483	186,628	198,562	181,557	155,539	196,505	+2.10	-21.67	+26.34

TABLE V

CHANGES IN MULTIPLE SECTIONS OF THE OS CALCIS IN

COUNTS DURING THE BED REST PHASE OF T

SUBJECT: GEORGE McNEIL

Position of Section	Regular Tracing A 2/1/69	Regular Tracing B 3/28/69	Regular Tracing C 5/7/69	Regular Tracing D 6/3/69	Regular Tracing E 7/14/69	Regu Trac F 8/
2 mm up	12532	13157	13363	13061	13017	13
1 mm up	12443	13255	13293	12943	12551	12
CONVENTIONAL TRACE	11818	12379	12772	12049	11986	12
1 mm down	11794	11956	12520	12453	12404	12
2 mm down	11679	11456	12133	11947	11856	11
3 mm down	11312	11777	11934	11864	11759	11
4 mm down	10988	11896	11930	11713	11564	11
5 mm down	10784	11371	11402	11344	11299	11
6 mm down	10628	11370	11940	11172	11142	11
7 mm down	10576	11305	11447	11165	11105	11
8 mm down	10616	11268	11777	11046	11005	11
9 mm down	10649	11015	11104	10943	10935	11
10 mm down	10539	10819	10856	10651	10639	10
11 mm down	10557	10615	10753	10517	10322	10
12 mm down	10411	10271	10605	10459	10225	10
13 mm down	10253	10897	10937	10539	10432	10
14 mm down	10063	10565	10753	10458	10393	10
15 mm down	9740	10000	10328	10189	10068	10
16 mm down	9427	10332	10502	9961	9817	10
17 mm down	8861	9543	10006	9717	9562	9
18 mm down	8483	8913	9413	9287	8950	9
19 mm down	7935	8426	9115	8996	8545	8
20 mm down	7495	8286	8631	8604	8342	8
21 mm down	7151	8038	8108	7942	7723	7
22 mm down	6722	7478	7678	7626	7472	7
23 mm down	6422	7019	7431	7233	7009	7
24 mm down	6118	6519	6833	6693	6579	6
25 mm down	5879	6091	6204	6052	5997	6
26 mm down	5629	5695	5781	5562	5558	5
27 mm down	5400	5491	5521	5418	5225	5
28 mm down	5211	5279	5319	5042	4955	5
29 mm down	5004	5003	5005	4838	4675	4
30 mm down	4778	4794	4810	4687	4566	4
31 mm down	4583	4596	4641	4493	4446	4
32 mm down	4504	4540	4607	4407	4313	4
33 mm down	4459	4498	4561	4372	4362	4
34 mm down	4375	4422	4482	4235	4228	4
35 mm down	4157	4244	4325	4100	4015	4
36 mm down	3793	3846	3855	3788	3643	3
37 mm down	3278	3324	3372	3235	3198	3
38 mm down	2537	2865	2949	2727	2684	2
Total	329,583	344,644	352,996	343,528	338,566	345,58

TABLE V

CHANGES IN MULTIPLE SECTIONS OF THE QS CALCIS IN TERMS OF INTEGRATOR COUNTS DURING THE BED REST PHASE OF THE PROJECT

ORGE McNEIL

Regular Tracing A 2/1/69	Regular Tracing B 3/28/69	Regular Tracing C 5/7/69	Regular Tracing D 6/3/69	Regular Tracing E 7/14/69	Regular Tracing F 8/8/69	Per Cent Change between Tests		
						A to C	C to E	E to F
12532	13157	13363	13061	13017	13350	+6.63	-2.59	+2.56
12443	13255	13293	12943	12551	12673	+6.83	-5.58	+0.97
11818	12379	12772	12049	11986	12379	+8.07	-6.15	+3.28
11794	11956	12520	12453	12404	12640	+6.15	-0.93	+1.90
679	11456	12133	11947	11856	11955	+3.89	-2.28	+0.83
11312	11777	11934	11864	11759	11852	+5.50	-1.47	+0.79
10988	11896	11930	11713	11564	11762	+8.57	-3.07	+1.71
10784	11371	11402	11344	11299	11965	+5.73	-0.90	+5.89
10628	11370	11940	11172	11142	11232	+12.34	-6.68	+0.81
10576	11305	11447	11165	11105	11470	+8.23	-2.99	+3.29
10616	11268	11777	11046	11005	11363	+10.94	-6.55	+3.25
10649	11015	11104	10943	10935	11109	+4.27	-1.52	+1.59
10539	10819	10856	10651	10639	10842	+3.01	-2.00	+1.91
10557	10615	10753	10517	10322	10651	+1.86	-4.01	+3.19
10411	10271	10605	10459	10225	10769	+1.86	-3.58	+5.32
10253	10897	10937	10539	10432	10615	+6.67	-4.62	+1.75
10063	10565	10753	10458	10393	10434	+6.86	-3.35	+0.39
9740	10000	10328	10189	10068	10105	+6.04	-2.52	+0.37
9427	10332	10502	9961	9817	10156	+11.40	-6.52	+3.45
8861	9543	10006	9717	9562	9723	+12.92	-4.44	+1.68
8483	8913	9413	9287	8950	9082	+10.96	-4.92	+1.47
7935	8426	9115	8996	8545	8763	+14.87	-6.25	+2.55
7495	8286	8631	8604	8342	8486	+15.16	-3.35	+1.73
7151	8038	8108	7942	7723	7920	+13.38	-4.75	+2.55
6722	7478	7678	7626	7472	7603	+14.22	-2.68	+1.75
6422	7019	7431	7233	7009	7051	+15.71	-5.68	+0.60
6118	6519	6833	6693	6579	6892	+11.69	-3.72	+4.76
5879	6091	6204	6052	5997	6050	+5.53	-3.34	+0.88
5629	5695	5781	5562	5558	5636	+2.70	-3.86	+1.40
300	5491	5521	5418	5225	5359	+2.24	-5.36	+2.56
5211	5279	5319	5042	4955	5022	+2.07	-6.84	+1.35
5004	5003	5005	4838	4675	4749	+0.02	-6.59	+1.58
4778	4794	4810	4687	4566	4681	+0.67	-5.07	+2.52
4583	4596	4641	4493	4446	4478	+1.26	-4.20	+0.72
4504	4540	4607	4407	4313	4441	+2.29	-6.38	+2.97
4459	4498	4561	4372	4362	4410	+2.29	-4.36	+1.10
4375	4422	4482	4235	4228	4258	+2.44	-5.67	+0.71
4157	4244	4325	4100	4015	4015	+4.04	-7.17	+0.90
3793	3846	3855	3788	3643	3688	+1.63	-5.50	+1.23
3278	3324	3372	3235	3198	3175	+2.87	-5.16	-0.72
2537	2865	2949	2727	2684	2744	+16.24	-8.99	+2.23
329,583	344,644	352,996	343,528	338,566	345,584	+7.10	-4.09	+2.07

observations concerning this study were given by Trueta[4] at the Conference on Bone Biodynamics at the Ford Hospital, Detroit in 1964.

In this study, adult mongrel dogs were used. The effect of muscle contraction on the blood supply of the adjacent bone was investigated by determinations of the intra-osseous pressure in the tibia of the dog during varying conditions of muscle activity.

They found that muscular contraction seems to influence the blood flow in bone in two ways: (a) by the occlusion of the venous outflow, which leads to an increase in intramedullary pressure; and (b) by the rapid emptying of the intra-osseous venous system following muscle relaxation, which causes the intra-osseous pressure to fall.

Subsequent Trips on this Project

Following the third trip by the T.W.U. team to San Francisco to take radiographs of men engaged in bed rest projects at the U. S. Public Health Service Hospital, nine additional trips were made. The dates on which all 12 sets of x-rays were exposed were the following: 2/1/69; 3/28/69; 5/7/69; 6/3/69; 7/14/69; 8/8/69; 9/15/69; 10/14/69; 11/26/69; 12/17/69; 2/9/70; and 3/18/70. Two groups of men participated in the study through the year 69 - 70, with the following phases of the study covered: two 12-week bed rests, one six-week bed rest, an initial ambulatory period for three men, and a final ambulatory period.

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Second Twelve Weeks of the Investigation of the First Group of Men-- Os Calcis

During the second 12-week bed rest period, Robinson and Kolb continued with bed rest, but with 1.4 grams of phosphate a day added as a dietary supplement. During this same period, Bratcher, Diaz, and McNeil also continued with bed rest, but without the phosphate supplementation. Tables I, II, III, IV, and V continue with the data on bone density of the multiple os calcis sections, with the second bed rest period which extended from April 21 through July 14, as has been noted.

As is characteristic of subjects in a study of this type, past dietary history and other background factors lead to different responses to the same treatment. Robinson, for example, increased in bone density in every section of the os calcis which was scanned during the bed rest under consideration (Table I, C to E). Kolb, on the other hand, alternated throughout the 42 sections scanned in his os calcis between positive and negative changes in bone density, with an overall value of +0.58 per cent change during the 12-week period, in contrast with Robinson's +5.63 per cent.

Bratcher, with no phosphate supplementation during the second bed rest (Table III, C to E) showed 5 positive and 30 negative bone density changes in the 35 sections scanned across the os calcis, with an overall change of -1.44 per cent.. Diaz, also with no phosphate supplementation during this bed rest period, showed an overall bone density change in the

sections across the os calcis of -21.67 per cent. See Table IV. McNeil, during the same period, exhibited an overall bone density change of -4.09 per cent in his multiple sections of the os calcis. See Table V.

Final Portion of the Study Involving the First Group of Subjects -- Os Calcis

After the first two bed rest periods had been completed, only three of the first group of men continued with an additional 6-week bed rest period. These were Robinson, Kolb, and McNeil. Of these, the first two had no exercise or phosphate supplementation and the third (McNeil) had phosphate. A short period of ambulation closed the project for T.W.U. for all five of these men.

		Bone Density Changes	
Table	Subject	Third Bed Rest	Final Ambulation
I	Robinson	-12.80	+3.41
II	Kolb	-1.25	+3.70
III	Bratcher	X	+2.32
IV	Diaz	X	+26.34
V	McNeil	+2.07	X

Changes in First Group of Subjects--

Hand and Wrist

Hand Phalanx 4/2, First Bed Rest. Of the two men who engaged in horizontal bed rest without exercise, both lost in bone density in hand phalanx 4/2 during the first 12 weeks of the investigation. On the other hand, the three men who engaged in bed rest with exercise all gained in bone density in this finger area. The following gives more explicit findings concerning this aspect of the study.

Table	Subject	Bone Density Change (per cent)	Engaged in Exercise?
IX	Robinson	-3.53	No
X	Kolb	-10.78	No
XI	Bratcher	+9.00	Yes
XII	Diaz	+9.73	Yes
XIII	McNeil	+9.28	Yes

Hand Phalanx 4/2, Second Bed Rest. The data for bone density changes in hand phalanx 4/2 during the second 12-week bed rest may be summarized as follows:

Table	Subject	Bone Density Changes during Second 12-week Bed Rest	Dietary Supplement or Exercise
IX	Robinson	+0.17	Phosphate No Exercise
X	Kolb	+9.91	Phosphate No Exercise
XI	Bratcher	-24.38	Neither
XII	Diaz	-20.03	Neither
XIII	McNeil	-12.86	Neither

Hand Phalanx 4/2, Third Bed Rest. Of the first group of men, as has been noted, only Robinson, Kolb and McNeil took part in the third bed rest, during which neither exercise nor phosphate supplementation was required of anyone except McNeil, who was given the extra phosphate.

The findings from the third bed rest and the subsequent final ambulatory period related to the behavior of hand phalanx 4/2 were as follows:

		Bone Density Change		
Table	Subject	Third Bed Rest	Treatment during Bed Rest	Final Ambulatory Period
IX	Robinson	+0.71	None	+4.57
X	Kolb	-7.06	None	+9.71
XI	Bratcher	X	None	+18.43
XII	Diaz	X	None	+24.34
XIII	McNeil	-0.12	Phosphate	No final ambulatory period

TABLE IX

CHANGES IN MULTIPLE SECTIONS OF HAND P-

INTEGRATOR COUNTS DURING THE BED REST

SUBJECT: RANDALL ROBINSON

Position of Section	A 2/1/69	B 3/28/69	C 5/7/69	D 6/3/69	E 7/14/69	F 8/8/69	9
Proximal End of the Phalanx	1500	1516	1457	1392	1463	1449	
1 mm up	1350	1451	1319	1221	1306	1306	
2 mm up	1207	1278	1193	1112	1141	1206	
3 mm up	1143	1214	1132	1065	1111	1131	
4 mm up	1119	1171	1100	1039	1095	1088	
5 mm up	1061	1109	1049	988	1038	1038	
6 mm up	1056	1104	1071	993	1021	1048	
7 mm up	1095	1134	1090	1017	1073	1061	
8 mm up	1109	1151	1095	1042	1092	1084	
9 mm up	1123	1167	1116	1036	1096	1079	
10 mm up	1113	1179	1108	1055	1017	1069	
11 mm up	1099	1171	1093	1029	1015	1107	
12 mm up	1130	1156	1073	1017	1088	1089	
13 mm up	1094	1121	1030	979	1055	1072	
14 mm up	1054	1090	997	950	1025	1032	
15 mm up	1021	1045	969	920	983	1003	
16 mm up	993	1030	953	893	952	968	
17 mm up	970	1001	918	898	930	955	
18 mm up	968	997	907	899	928	959	
19 mm up	1014	991	918	895	921	942	
20 mm up	1001	1015	953	929	930	985	
21 mm up	988	1015	939	881	958	952	
22 mm up	979	1003	949	888	932	931	
23 mm up	974	999	925	866	932	967	
24 mm up	974	993	924	869	950	951	
25 mm up	992	998	938	890	958	962	
26 mm up	957	981	902	863	932	905	
27 mm up	900	826	807	824	873	842	
Total	29,984	30,916	28,925	27,455	28,975	29,181	2

TABLE IX

ANGES IN MULTIPLE SECTIONS OF HAND PHALANX 4-2 IN TERMS OF NTEGRATOR COUNTS DURING THE BED REST PHASE OF THE PROJECT

[redacted] 5/7/69	D 6/3/69	E 7/14/69	F 8/8/69	G 9/15/69	H 10/14/69	Per Cent Change between Tests			
						A to C	C to E	E to F	F to H
1457	1392	1463	1449	1463	1477	-2.87	+0.41	-0.96	+1.93
1319	1221	1306	1306	1410	1431	-2.30	-0.98	±0.00	+9.57
1193	1112	1141	1206	1257	1985	-1.16	-4.36	+5.70	+6.55
1132	1065	1111	1131	1183	1247	-1.96	-1.86	+1.80	+10.26
1100	1039	1095	1088	1131	1198	-1.70	-0.45	-0.64	+10.11
1049	988	1038	1038	1065	1058	-1.13	-1.05	±0.00	+1.93
1071	993	1021	1048	1066	1085	+1.42	-4.67	+2.64	+3.53
1090	1017	1073	1061	1092	1164	-0.46	-1.56	-1.12	+9.71
1095	1042	1092	1084	1108	1161	-1.26	-0.27	-0.73	+7.10
1116	1036	1096	1079	1115	1175	-0.62	-1.79	-1.55	+8.90
1108	1055	1017	1069	1125	1142	-0.45	-8.21	+5.11	+6.83
1093	1029	1015	1107	1125	1193	-0.55	-7.14	+9.06	+7.77
1073	1017	1088	1089	1097	1123	-5.04	+1.40	+0.09	+3.12
1030	979	1055	1072	1075	1099	-5.85	+2.43	+1.61	+2.52
997	950	1025	1032	1032	1057	-5.41	+2.81	+0.68	+2.42
969	920	983	1003	1021	1042	-5.09	+1.44	+2.03	+3.89
953	898	952	968	978	992	-4.03	-0.10	+1.68	+2.48
918	898	930	955	976	983	-5.36	+1.31	+2.69	+2.93
907	899	928	959	960	969	-6.30	+2.32	+3.34	+1.04
918	895	921	942	958	983	-9.47	+0.33	+2.28	+4.35
[redacted]	929	930	985	990	989	-4.80	-2.41	+5.91	+0.41
[redacted]	881	958	952	980	984	-4.96	+2.02	-0.63	+3.36
949	888	932	931	959	967	-3.06	-1.79	-0.11	+3.87
925	866	932	967	956	962	-5.03	+0.76	+3.76	-0.52
924	869	950	951	962	957	-5.13	+2.81	+0.11	+0.63
938	890	958	962	970	975	-5.44	+2.13	+0.42	+1.35
902	863	932	905	931	919	-5.75	+3.32	-2.90	+1.55
807	824	873	842	870	899	-10.33	+8.18	-3.55	+6.77
28,925	27,455	28,975	29,181	29,855	30,516	-3.53	+0.17	+0.71	+4.57

TABLE X

CHANGES IN MULTIPLE SECTIONS OF HAND PHALANX 4-2

INTEGRATOR COUNTS DURING THE BED REST PHASE OF

SUBJECT: FRED KOLB

Position of Section	A 2/1/69	B 3/28/69	C 5/7/69	D 6/3/69	E 7/14/69	F 8/8/69	G 9/15/69	H
Proximal End of the Phalanx	1401	1340	1256	1265	1350	1331	1321	
1 mm up	1313	1249	1165	1168	1318	1085	1186	
2 mm up	1111	1067	1046	1053	1088	979	1001	
3 mm up	1083	1036	1022	1026	1059	964	982	
4 mm up	1077	1000	994	1000	1033	968	977	
5 mm up	1073	1003	911	1011	1016	999	995	
6 mm up	1110	1059	953	1023	1063	1012	1038	
7 mm up	1113	1078	983	1057	1095	1002	1042	
8 mm up	1129	1058	969	1062	1115	1025	1037	
9 mm up	1121	1065	978	1066	1103	1062	1041	
10 mm up	1110	1055	964	1068	1079	1016	1022	
11 mm up	1085	1046	959	1038	1066	1013	1011	
12 mm up	1080	1035	947	1039	1042	1004	1080	
13 mm up	1054	996	919	1000	1006	955	959	
14 mm up	1011	982	926	991	1003	939	987	
15 mm up	1000	963	907	963	985	913	923	
16 mm up	997	951	898	952	958	908	945	
17 mm up	964	933	875	931	952	902	923	
18 mm up	948	881	845	910	894	858	905	
19 mm up	943	894	842	908	942	871	882	
20 mm up	903	886	810	882	909	855	874	
21 mm up	918	875	821	871	910	819	965	
22 mm up	890	867	798	855	880	842	848	
23 mm up	915	892	825	886	945	876	862	
24 mm up	912	892	827	879	909	840	880	
25 mm up	896	859	801	842	889	807	831	
26 mm up	713	700	623	663	749	554	660	
Total	27,870	26,662	24,864	26,409	27,358	25,399	26,077	

TABLE X

ANGES IN MULTIPLE SECTIONS OF HAND PHALANX 4-2 IN TERMS OF

NTEGRATOR COUNTS DURING THE BED REST PHASE OF THE PROJECT

C 5/7/69	D 6/3/69	E 7/14/69	F 8/8/69	G 9/15/69	H 10/14/69	Per Cent Change between Tests			
						A to C	C to E	E to F	F to H
1256	1265	1350	1331	1321	1426	-10.35	+7.48	-1.41	+7.14
1165	1168	1318	1085	1186	1281	-11.27	+13.13	-17.68	+18.06
1046	1053	1088	979	1001	1134	-5.85	+4.01	-10.02	+15.83
1022	1026	1059	964	982	1069	-5.63	+3.62	-8.97	+10.89
994	1000	1033	968	977	1071	-7.71	+3.92	-6.29	+10.64
911	1011	1016	999	995	1041	-15.10	+11.52	-1.67	+4.20
953	1023	1063	1012	1038	1065	-14.14	+11.54	-4.80	+5.24
983	1057	1095	1002	1042	1093	-11.68	+11.39	-8.49	+9.08
969	1062	1115	1025	1037	1122	-14.17	+15.07	-8.07	+9.46
978	1066	1103	1062	1041	1144	-12.76	+12.78	-3.72	+7.72
964	1068	1079	1016	1022	1141	-13.15	+11.93	-5.84	+12.30
959	1038	1066	1013	1011	1107	-11.61	+11.16	-4.97	+9.28
947	1039	1042	1004	1080	1093	-12.31	+10.03	-3.65	+8.86
919	1000	1006	955	959	1063	-12.81	+9.47	-5.07	+11.31
926	991	1003	939	987	1033	-8.41	+8.31	-6.38	+10.01
907	963	985	913	923	993	-9.30	+8.60	-7.31	+8.76
898	952	958	908	945	980	-9.93	+6.68	-5.22	+7.93
875	931	952	902	923	969	-9.23	+8.80	-5.25	+7.43
845	910	894	858	905	951	-10.86	+5.80	-4.03	+10.84
842	908	942	871	882	935	-10.71	+11.88	-7.54	+7.35
810	882	909	855	874	897	-10.30	+12.22	-5.94	+4.91
821	871	910	819	965	894	-10.57	+10.84	-10.00	+9.16
798	855	880	842	848	878	-10.34	+10.28	-4.32	+4.27
825	886	945	876	862	894	-9.84	+14.54	-7.30	+2.05
807	879	909	840	880	926	-9.32	+9.91	-7.59	+10.24
801	842	889	807	831	881	-10.60	+10.99	-9.22	+9.17
623	663	749	554	660	785	-12.62	+20.22	-26.03	+41.70
24,864	26,409	27,358	25,399	26,077	27,866	-10.78	+9.91	-7.06	+9.71

TABLE XI

CHANGES IN MULTIPLE SECTIONS OF THE HAND PHALANX 4-

COUNTS DURING THE BED REST PHASE OF T

SUBJECT: FRED BRATCHER

Position of Section	A 2/1/69	B 3/28/69	C 5/7/69	D 6/3/69	E 7/14/69	F 8/
Proximal End of the Phalanx	1520	1549	1608	1487	1267	1
1 mm up	1518	1450	1627	1448	1176	1
2 mm up	1322	1299	1423	1270	1047	1
3 mm up	1224	1251	1339	1192	981	1
4 mm up	1184	1181	1287	1195	962	1
5 mm up	1180	1168	1274	1152	954	1
6 mm up	1164	1169	1269	1144	948	1
7 mm up	1176	1184	1283	1178	959	1
8 mm up	1164	1174	1265	1163	947	1
9 mm up	1151	1159	1251	1158	948	1
10 mm up	1145	1132	1222	1125	930	1
11 mm up	1107	1117	1184	1091	899	1
12 mm up	1080	1070	1135	1072	890	1
13 mm up	1020	1037	1115	1027	851	1
14 mm up	1000	993	1072	998	831	1
15 mm up	969	968	1060	968	808	1
16 mm up	968	976	1064	982	815	1
17 mm up	959	964	1070	980	802	1
18 mm up	994	964	1103	997	833	1
19 mm up	1001	995	1108	996	824	1
20 mm up	1004	988	1125	1009	846	1
21 mm up	1045	1017	1164	1032	861	1
22 mm up	1026	1031	1168	1039	857	1
23 mm up	1004	1029	1148	1002	852	1
24 mm up	939	1034	1023	949	793	1
25 mm up	848	906	919	853	713	1
26 mm up	803	844	869	806	684	1
27 mm up	688	801	741	738	616	1
Total	30,203	30,450	32,922	30,051	24,894	29,

TABLE XI

CHANGES IN MULTIPLE SECTIONS OF THE HAND PHALANX 4-2 IN TERMS OF INTEGRATOR COUNTS DURING THE BED REST PHASE OF THE PROJECT

ED BRATCHER

	A 2/1/69	B 3/28/69	C 5/7/69	D 6/3/69	E 7/14/69	F 8/8/69	Per Cent Change between Tests		
							A to C	C to E	E to F
nd									
	1520	1549	1608	1487	1267	1472	+5.79	-21.21	+16.18
	1518	1450	1627	1448	1176	1474	+7.18	-27.72	+25.34
	1322	1299	1423	1270	1047	1343	+7.64	-26.42	+28.27
	1224	1251	1339	1192	981	1242	+9.40	-26.74	+26.60
	1184	1181	1287	1195	962	1136	+8.70	-25.25	+18.09
	1180	1168	1274	1152	954	1120	+7.97	-25.12	+17.40
	1164	1169	1269	1144	948	1123	+9.02	-25.29	+18.46
	1176	1184	1283	1178	959	1110	+9.10	-25.25	+15.74
	1164	1174	1265	1163	947	1139	+8.68	-25.14	+20.27
	1151	1159	1251	1158	948	1125	+9.21	-24.58	+18.67
	1145	1132	1222	1125	930	1096	+6.72	-23.89	+17.85
	1107	1117	1184	1091	899	1051	+6.95	-24.07	+16.91
	1080	1070	1135	1072	890	1018	+5.09	-21.58	+14.38
	1020	1037	1115	1027	851	987	+9.31	-23.68	+15.98
	1000	993	1072	998	831	969	+7.20	-22.48	+16.61
	969	968	1060	968	808	933	+9.39	-23.77	+15.47
	968	976	1064	982	815	930	+9.92	-23.40	+14.11
	959	964	1070	980	802	925	+11.57	-25.05	+15.34
	994	964	1103	997	833	949	+10.96	-24.48	+13.92
	1001	995	1108	996	824	983	+10.69	-25.63	+19.30
	1004	988	1125	1009	846	985	+12.05	-24.80	+16.43
	1045	1017	1164	1032	861	1005	+11.39	-26.03	+16.72
	1026	1031	1168	1039	857	1019	+13.84	-26.63	+18.90
	1004	1029	1148	1002	852	985	+14.34	-25.78	+15.61
	939	1034	1023	949	793	942	+8.94	-22.48	+18.79
	848	906	919	853	713	843	+8.37	-22.41	+18.23
	803	844	869	806	684	810	+8.22	-21.29	+18.42
	688	801	741	738	616	767	+7.70	-16.87	+24.51
	30,203	30,450	32,922	30,051	24,894	29,481	+9.00	-24.38	+18.43

TABLE XII

CHANGES IN MULTIPLE SECTIONS OF THE HAND PHALANX 4-2 IN TERMS OF INTEGRATOR COUNTS DURING THE BED REST PHASE OF THE PROJECT

SUBJECT: ALFREDO DIAZ

Position of Section	A	B	C	D	E	F	Per Cent Change between Tests		
	2/1/69	3/28/69	5/7/69	6/3/69	7/14/69	8/8/69	A to C	C to E	E to F
Proximal End of the Phalanx	1135	1218	1276	1214	1016	1183	+12.42	-20.38	+16.44
1 mm up	985	1064	1148	1071	848	1122	+16.55	-26.13	+32.31
2 mm up	855	965	1032	944	787	951	+20.70	-23.74	+20.84
3 mm up	792	912	931	905	758	898	+17.55	-18.58	+18.47
4 mm up	822	890	878	875	702	901	+6.81	-20.04	+28.35
5 mm up	813	868	872	870	722	871	+7.26	-17.20	+20.64
6 mm up	831	893	895	874	728	889	+7.70	-18.66	+22.12
7 mm up	835	883	902	899	738	918	+8.02	-18.18	+24.39
8 mm up	839	879	910	890	761	928	+8.46	-16.37	+21.94
9 mm up	842	882	904	888	756	922	+7.36	-16.37	+21.96
10 mm up	847	865	910	880	761	928	+7.44	-16.37	+21.94
11 mm up	842	888	920	889	787	930	+9.26	-14.46	+18.17
12 mm up	845	888	907	887	768	924	+7.34	-15.32	+20.31
13 mm up	822	855	911	874	768	914	+10.83	-15.70	+19.01
14 mm up	800	839	877	849	696	882	+9.62	-20.64	+26.72
15 mm up	790	822	867	831	687	868	+9.75	-20.76	+26.35
16 mm up	798	813	868	823	689	879	+8.77	-20.62	+27.58
17 mm up	796	818	867	832	708	884	+8.92	-18.34	+24.86
18 mm up	782	837	882	847	710	894	+12.79	-19.50	+25.91
19 mm up	787	875	872	860	681	868	+10.80	-21.90	+27.46
20 mm up	825	842	879	843	663	882	+6.54	-24.57	+33.03
21 mm up	817	843	878	827	664	858	+7.47	-24.37	+29.22
22 mm up	797	828	867	818	678	866	+8.78	-21.80	+27.73
23 mm up	812	845	869	792	655	861	+7.02	-24.63	+31.45
24 mm up	780	816	846	772	651	829	+8.46	-23.05	+27.34
25 mm up	740	771	766	704	598	749	+3.51	-21.93	+25.25
Total	21,629	22,[redacted]	23,734	22,758	18,980	23,599	+9.73	[redacted]-20.03	+24.34

TABLE XIII

CHANGES IN MULTIPLE SECTIONS OF THE HAND PHALANX 4-2 IN TERMS OF INTEGRATOR COUNTS DURING THE BED REST PHASE OF THE PROJECT

SUBJECT: GEORGE McNEIL

Position of Section	A 2/1/69	B 3/28/69	C 5/7/69	D 6/3/69	E 7/14/69	F 8/8/69	Per Cent Change between Tests		
							A to C	C to E	E to F
Proximal End of the Phalanx	1776	1830	1882	1811	1669	1625	+5.97	-11.32	-2.64
1 mm up	1583	1636	1716	1540	1458	1432	+8.40	-15.03	-1.79
2 mm up	1318	1449	1477	1404	1332	1346	+12.06	-9.82	+1.05
3 mm up	1222	1375	1382	1315	1272	1257	+13.09	-7.96	-1.18
4 mm up	1224	1321	1314	1294	1249	1215	+7.35	-4.95	-2.72
5 mm up	1174	1314	1320	1299	1248	1214	+12.44	-5.45	-2.72
6 mm up	1257	1314	1301	1264	1251	1190	+3.50	-3.84	-4.88
7 mm up	1262	1287	1316	1265	1195	1168	+4.28	-9.19	-2.26
8 mm up	1200	1229	1281	1236	1158	1137	+6.75	-9.60	-1.81
9 mm up	1181	1203	1237	1225	1088	1105	+4.74	-12.04	+1.56
10 mm up	1144	1184	1212	1197	1053	1091	+5.94	-13.12	+3.61
11 mm up	1113	1147	1187	1154	1040	1050	+6.65	-12.38	+0.96
12 mm up	1105	1117	1151	1154	1011	1034	+4.16	-12.16	+2.27
13 mm up	1081	1130	1127	1124	1097	1105	+4.26	-2.66	+0.73
14 mm up	1044	1094	1089	1094	1077	1088	+4.31	-1.10	+1.02
15 mm up	1014	1059	1082	1082	940	985	+6.71	-13.12	+4.79
16 mm up	1022	1043	1080	1055	961	946	+5.68	-11.02	-1.56
17 mm up	1020	1039	1074	1057	935	943	+5.29	-12.94	+0.86
18 mm up	1021	1043	1073	1053	936	947	+5.09	-12.77	+1.18
19 mm up	1001	1030	1067	1035	959	938	+6.59	-10.12	-2.19
20 mm up	987	1016	1047	1037	913	938	+6.08	-12.80	+2.74
21 mm up	987	1021	1048	1095	932	933	+6.18	-11.07	+0.11
22 mm up	1033	1067	1150	1122	980	971	+11.33	-14.78	-0.92
23 mm up	1098	1095	1238	1147	1009	987	+12.75	-18.50	-2.18
24 mm up	1124	1130	1269	1207	1039	1085	+12.90	-18.12	+4.43
25 mm up	1067	1131	1327	1159	1028	1068	+24.37	-22.53	+3.89
26 mm up	1096	1084	1481	1068	963	966	+35.13	-34.98	+0.31
27 mm up	1030	923	1244	912	855	848	+20.78	-31.27	-0.82
Total	32,184	33,311	35,172	33,405	30,648	30,612	+9.28	-12.86	-0.12

Hand Phalanx 5/2, First Bed Rest. During the first 12-week bed rest by the first group of participants, the bone density changes in hand phalanx 5/2 were the following:

Table	Subject	Exercise	Change in Bone Density (per cent)
XVII	Robinson	no	+5.66
XVIII	Kolb	no	+3.32
XIX	Bratcher	yes	+5.92
XX	Diaz	yes	-2.73
XXI	McNeil	yes	-6.33

As in other cases with which we have worked, the second phalanx of the fifth finger has not been increased with the use of the Exer-Genie, probably because this finger is not involved with the use of this exerciser. The subjects appear to follow individual characteristics rather than muscle pull in the finger causing bone density increase.

Hand-Phalanx 5/2, Second Bed Rest. During the second 12-week bed rest, the hand phalanx 5/2 bone density changes are given below. The phosphate supplementation appeared to have improved the bone density of the hand phalanx under consideration.

Table	Subject	Phosphate	Change in Bone Density (per cent)
XVII	Robinson	yes	+8.64
XVIII	Kolb	yes	+6.63
XIX	Bratcher	no	-10.61
XX	Diaz	no	-9.26
XXI	McNeil	no	-3.45

Hand Phalanx 5/2, Third Bed Rest. As in the case of other bones which were evaluated, only three men participated in the third bed rest, as noted below. These were Robinson, Kolb, and McNeil.

Table	Subject	Phosphate	Change in Bone Density (per cent)
XVII	Robinson	no	-3.95
XVIII	Kolb	no	-14.49
XIX	Bratcher	X	X
XX	Diaz	X	X
XXI	McNeil	yes	+4.11

Hand Phalanx 5/2, Final Ambulatory Period. The performance of hand phalanx 5/2 during the final ambulatory periods of the men of this first group is given below. All of the men did not begin their final ambulatory periods at the same time. Robinson began his ambulation on 8/25/69,

with radiographs taken by T.W.U. on 8/8/69, 9/15/69, and 10/14/69. The last date was his final radiograph. Kolb's pattern was exactly like that of Robinson. The final ambulation periods of Bratcher and Diaz began on July 14th and continued until August 8th.

Table	Subject	Change in Bone Density during Last Ambulatory Period (per cent)
XVII	Robinson	+14.25
XVIII	Kolb	+6.50
XIX	Bratcher	+4.67
XX	Diaz	+11.57
XXI	McNeil	None

As noted, McNeil left the study unexpectedly on the day when his last radiograph was to be given, and his last short ambulatory period could not be completed.

TABLE XVII

CHANGES IN MULTIPLE SECTIONS OF THE HAND PHALANX 5-2 IN TERMS OF INTEGRATOR COUNTS DURING THE BED REST PHASE OF THE PROJECT

SUBJECT: RANDALL ROBINSON

Position of Section	A 2/1/69	B 3/28/69	C 5/7/69	D 6/3/69	E 7/14/69	F 8/8/69	G 9/15/69	H 10/14/69	Per Cent Change between Tests			
									A to C	C to E	E to F	F to
Proximal End of the Phalanx	1083	1135	1124	1189	1266	1114	1087	1247	+3.79	+12.63	-12.01	+11.
1 mm up	895	955	950	999	1025	1011	910	1213	+6.15	+7.89	-1.37	+19.
2 mm up	788	847	838	906	936	890	813	1076	+6.35	+11.69	-4.91	+20.
3 mm up	754	808	792	868	910	823	780	987	+5.04	+14.90	-9.56	+19.
4 mm up	710	768	783	833	888	789	749	907	+10.28	+13.41	-11.15	+14.
5 mm up	704	757	748	794	782	798	730	909	+6.25	+4.55	+2.05	+13.
6 mm up	706	750	757	799	794	772	722	865	+7.22	+4.89	-2.77	+12.
7 mm up	695	733	729	793	750	770	725	872	+4.89	+2.88	+2.67	+13.
8 mm up	704	739	728	764	749	754	698	837	+3.41	+2.88	+0.67	+11.
9 mm up	706	724	730	742	745	746	681	828	+3.40	+2.05	+0.13	+10.
10 mm up	672	713	684	718	756	733	641	835	+1.79	+10.53	-3.04	+13.
11 mm up	643	671	670	700	741	703	626	799	+4.20	+10.60	-5.13	+13.
12 mm up	630	655	659	675	730	690	613	839	+4.60	+10.77	-5.48	+21.
13 mm up	616	645	646	654	725	681	602	755	+4.87	+12.23	-6.07	+10.
14 mm up	604	647	647	657	713	680	605	754	+7.12	+10.20	-4.63	+10.
15 mm up	572	646	642	665	688	681	602	756	+12.24	+7.17	-1.02	+11.
16 mm up	627	674	678	703	701	702	608	786	+9.00	+3.39	+0.14	+11.
17 mm up	655	702	695	718	758	733	631	820	+6.11	+9.06	-3.30	+11.
18 mm up	689	744	734	762	792	758	676	811	+6.53	+7.90	-4.29	+6.
19 mm up	708	765	729	767	807	786	700	943	+2.97	+10.70	-2.60	+19.
Total	14,161	15,078	14,963	15,706	16,256	15,614	14,199	17,839	+5.66	+8.64	-3.95	+14.

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TABLE XVIII

CHANGES IN MULTIPLE SECTIONS OF HAND PHALANX 5-2 IN TERMS OF INTEGRATOR COUNTS DURING THE BED REST PHASE OF THE PROJECT

SUBJECT: FRED KOLB

Position of Section	A 2/1/69	B 3/28/69	C 5/7/69	D 6/3/69	E 7/14/69	F 8/8/69	G 9/15/69	H 10/14/69	Per Cent Change between Tests A to C	C to E	E to F	F to H
Proximal End of the Phalanx	1053	1018	1045	1087	1089	985	887	1051	-0.76	+4.21	-9.55	+6.70
1 mm up	919	960	951	943	959	868	849	893	+3.48	+0.84	-9.49	+2.88
2 mm up	780	818	809	818	896	720	687	777	+3.72	+10.75	-19.64	+7.92
3 mm up	752	772	768	801	874	675	665	759	+2.13	+13.80	-22.77	+12.44
4 mm up	753	767	766	798	783	688	703	751	+1.73	+2.22	-12.13	+9.16
5 mm up	745	769	758	779	797	681	684	760	+1.74	+5.15	-14.55	+11.60
6 mm up	738	738	759	792	800	689	679	743	+2.84	+5.40	-13.88	+7.84
7 mm up	716	732	753	791	802	674	684	741	+5.17	+6.51	-15.96	+9.94
8 mm up	700	719	741	753	785	666	651	710	+5.86	+5.94	-15.16	+6.61
9 mm up	677	687	695	726	794	638	632	684	+2.66	+14.24	-19.65	+7.21
10 mm up	666	681	687	715	770	637	615	666	+3.15	+12.08	-17.27	+4.55
11 mm up	669	669	682	710	774	631	612	657	+1.94	+13.49	-18.48	+4.12
12 mm up	651	664	668	693	670	623	612	646	+2.61	+0.30	-7.01	+3.69
13 mm up	628	652	651	674	658	630	605	620	+3.66	+1.08	-4.26	-1.59
14 mm up	592	619	633	656	688	579	585	606	+6.93	+8.69	-15.84	+4.66
15 mm up	610	627	648	676	696	583	588	620	+6.23	+7.41	-16.24	+6.35
16 mm up	663	654	685	715	738	617	629	668	+3.32	+7.74	-16.40	+8.27
17 mm up	714	705	733	762	790	666	666	719	+2.66	+7.78	-15.70	+7.96
18 mm up	673	684	722	712	730	656	672	674	+7.28	+1.11	-10.14	+2.74
Total	13,699	13,935	14,154	14,601	15,093	12,906	12,705	13,745	+3.32	+6.63	-14.49	+6.50

TABLE XIX

CHANGES IN MULTIPLE SECTIONS OF HAND PHALANX 5-2 IN TERMS OF INTEGRATOR COUNTS DURING THE BED REST PHASE OF THE PROJECT

SUBJECT: FRED BRATCHER

Position of Section	A 2/1/69	B 3/28/69	C 5/7/69	D 6/3/69	E 7/14/69	F 8/8/69	Per Cent Change between Tests		
							A to C	C to E	E to F
Proximal End of the Phalanx	1098	1169	1157	1098	1007	1076	+5.37	-12.96	+6.85
1 mm up	958	1030	1017	990	906	944	+5.64	-10.47	+4.19
2 mm up	852	925	926	892	829	868	+8.69	-10.48	+4.70
3 mm up	837	864	875	840	801	826	+4.54	-8.46	+3.12
4 mm up	794	839	849	798	757	792	+6.93	-10.84	+4.62
5 mm up	780	821	838	788	760	787	+7.44	-9.31	+3.55
6 mm up	775	817	831	782	759	778	+7.23	-8.66	+2.50
7 mm up	763	802	812	774	745	774	+6.42	-8.25	+3.89
8 mm up	736	791	786	741	724	736	+6.79	-7.89	+1.66
9 mm up	718	747	767	713	699	718	+6.82	-8.87	+2.72
10 mm up	713	737	766	682	664	705	+7.43	-13.32	+6.17
11 mm up	710	723	750	682	643	704	+5.63	-14.27	+9.49
12 mm up	704	716	736	639	624	689	+4.55	-15.22	+10.42
13 mm up	698	724	732	668	667	689	+4.87	-8.88	+3.30
14 mm up	689	721	748	672	667	691	+8.56	-10.83	+3.60
15 mm up	690	734	746	688	686	682	+8.12	-8.04	-0.58
16 mm up	705	746	784	671	684	714	+11.21	-12.76	+4.39
17 mm up	730	763	798	655	680	732	+9.32	-14.79	+7.65
18 mm up	700	762	768	628	682	725	+9.71	-11.20	+6.30
19 mm up	660	725	679	556	634	672	+2.88	-6.63	+5.99
20 mm up	560	653	579	439	523	546	+3.39	-9.67	+4.40
Total	15,870	16,809	16,939	15,396	15,141	15,848	+5.92	-10.61	+4.67

TABLE XX

CHANGES IN MULTIPLE SECTIONS OF HAND PHALANX 5-2 IN TERMS OF INTEGRATOR COUNTS DURING THE BED REST PHASE OF THE PROJECT

SUBJECT: ALFREDO DIAZ

Position of Section	A 2/1/69	B 3/28/69	C 5/7/69	D 6/3/69	E 7/14/69	F 8/8/69	Per Cent Change between Tests		
							A to C	C to E	E to F
Proximal End of the Phalanx	832	817	805	751	689	741	-3.25	-14.41	+7.55
1 mm up	822	843	801	761	689	836	-2.55	-13.98	+21.34
2 mm up	710	731	692	644	592	694	-2.54	-14.45	+17.23
3 mm up	642	658	644	574	544	641	+0.31	-15.53	+17.83
4 mm up	612	613	596	531	519	587	-2.61	-12.92	+13.10
5 mm up	562	559	564	518	508	562	+0.36	-9.93	+10.63
6 mm up	564	581	564	513	510	568	±0.00	-9.57	+11.37
7 mm up	568	594	564	517	516	570	-0.70	-8.51	+10.47
8 mm up	574	585	545	524	511	580	-5.05	-6.24	+13.50
9 mm up	553	584	538	507	510	558	-2.71	-5.20	+9.41
10 mm up	535	556	523	502	488	547	-2.24	-6.69	+12.09
11 mm up	523	556	518	486	481	537	-0.96	-7.14	+11.64
12 mm up	528	549	524	485	471	527	-0.76	-10.11	+11.89
13 mm up	517	544	530	468	470	530	+2.51	-11.32	+12.77
14 mm up	546	588	538	505	531	535	-1.47	-1.30	+0.75
15 mm up	573	616	574	510	559	554	+0.17	-2.61	-0.89
16 mm up	613	603	474	498	481	551	-22.68	+1.48	+14.55
Total	10,274	10,577	9,994	9,294	9,069	10,118	-2.73	-9.26	+11.57

TABLE XXI

CHANGES IN MULTIPLE SECTIONS OF HAND PHALANX 5-2 IN TERMS OF INTEGRATOR COUNTS DURING THE BED REST PHASE OF THE PROJECT

SUBJECT: GEORGE McNEIL

Position of Section	A 2/1/69	B 3/28/69	C 5/7/69	D 6/3/69	E 7/14/69	F 8/8/69	Per Cent Change between Tests		
							A to C	C to E	E to F
Proximal End of the Phalanx	1199	1192	1199	1042	1108	1110	±0.00	-7.59	+0.18
1 mm up	1207	1236	1034	1285	1033	1083	-14.33	-0.10	+4.84
2 mm up	981	999	927	1101	907	1005	-5.50	-2.16	+10.80
3 mm up	912	906	841	964	836	907	-7.79	-0.59	+8.49
4 mm up	865	856	813	916	781	825	-6.01	-3.94	+5.63
5 mm up	829	830	790	864	739	780	-4.70	-6.46	+5.55
6 mm up	795	792	755	814	719	765	-5.03	-4.77	+6.40
7 mm up	756	761	728	760	692	709	-3.70	-4.95	+2.46
8 mm up	751	746	709	761	678	689	-5.59	-4.37	+1.62
9 mm up	733	729	695	748	659	638	-5.18	-5.18	-3.19
10 mm up	727	704	673	717	669	690	-7.43	-0.59	+3.14
11 mm up	688	680	632	697	621	652	-8.14	-1.74	+4.99
12 mm up	680	665	635	698	635	665	-6.62	±0.00	+4.72
13 mm up	657	647	609	675	599	615	-7.13	-1.64	+2.67
14 mm up	661	651	613	660	593	620	-7.26	-3.26	+4.55
15 mm up	669	649	622	669	592	582	-7.03	-4.82	-1.69
16 mm up	723	689	662	729	620	654	-8.44	-6.34	+5.48
17 mm up	765	738	713	743	692	720	-6.80	-2.95	+4.05
18 mm up	772	752	734	743	719	736	-4.92	-2.04	+2.36
19 mm up	711	717	679	666	652	697	-4.50	-3.98	+6.90
Total	16,081	15,939	15,063	16,252	14,544	15,142	-6.33	-3.45	+4.11

Bone Density Changes in Bones of the Wrist

The bones of the wrist which were radiographed along with the hand x-rays and which were evaluated for bone density included a section across the distal end of the radius, one across the distal end of the ulna, as well as a diagonal section across the capitate. The bone density changes which took part in these bones were evaluated along with that of other bone areas which have been considered. Table XXV includes the basic data for these bone sections.

Bone Density Changes in the Distal Radius throughout the Study of the First Group of Participants, First 12-Week Bed Rest. During the first bed rest, when two of the subjects did not exercise while three of them exercised, using the Exer-Genie, the following bone density changes took place in the section which was evaluated across the distal end of the radius:

Subject	Exercise	Bone Density Change (per cent)
Robinson	no	-4.88
Kolb	no	-8.78
Bratcher	yes	+5.97
Diaz	yes	+6.48
McNeil	yes	+2.12

Distal Section of Radius, Second 12-Week Bed Rest. During the second bed rest when phosphate supplementation was offered to some of the experimental subjects, some of the men gained and some lost in bone density, whether or not they received the extra phosphate. The data on this bed rest follows:

Subject	Phosphate	Bone Density Change (per cent)
Robinson	yes	+4.86
Kolb	yes	-7.33
Bratcher	no	-6.01
Diaz	no	-8.74
McNeil	no	+3.60

Distal Section of Radius, Six-Week Bed Rest. Three of the five subjects of this study took part in a six-week bed rest which followed the second 12-week bed rest. Of the three subjects, only one received any phosphate supplement, with no exercise being added to any of the programs. The treatment given to the men is shown in the following outline, together with the change in bone density.

Subject	Phosphate	Bone Density Change (per cent)
Robinson	no	-2.14
Kolb	no	-8.98
Bratcher	X	X
Diaz	X	X
McNeil	yes	+2.88

There appeared to be a difference between the negative and positive changes in bone density of the distal radius whether phosphate was provided or not, with the positive change in behalf of the one subject who received the phosphate.

Distal Section of Radius, Final Ambulatory Period. The following data show that the bone density of the distal end of the radius tended to show some increase during ambulation, with the exception of one man. It should be noted, however, that the ambulation periods were of relatively short duration, since the T.W.U. group did not make trips to San Francisc for the purpose of participating in this study except in connection with obtaining bed rest data. Securing x-rays from men who had reambulated was incidental. Hence the bed rest periods covered usually were not as long as those recorded by the Laboratory at the Hospital.

Subject	Change in Bone Density during Last Ambulatory Period (per cent)
Robinson	+3.25
Kolb	+9.83
Bratcher	+3.27
Diaz	+1.43
McNeil	No ambulation data

Bone Density Changes in the Distal Ulna throughout the First Group of Participants, First 12-Week Bed Rest. As in the case of the section across the distal end of the radius, the corresponding section across the ulna lost bone density to a minor extent in the men who did not exercise and gained in those who did.

Subject	Exercise	Bone Density Change (per cent)
Robinson	no	-1.49
Kolb	no	-4.34
Bratcher	yes	+5.79
Diaz	yes	+8.07
McNeil	yes	+2.00

Distal Section of Ulna, Second 12-Week Bed Rest. As in the situation with the distal radius, the distal ulna was not uniform with respect t

the changes in bone density with the subjects with and without phosphate supplementation. One subject who received extra phosphate had an increase and one had a decrease in bone density, with two decreases and one increase among the three men who were not given extra phosphate. See the following summary:

Subject	Phosphate	Bone Density Change (per cent)
Robinson	yes	+3.64
Kolb	yes	-6.74
Bratcher	no	-6.61
Diaz	no	+5.61
McNeil	no	-1.82

Distal Section of Ulna, Six-Week Bed Rest. As with other bone areas evaluated during the only six-week bed rest of this series, only three men took part in this section of the study as shown in the summary below. The men who received no phosphate were negative with respect to the bone density change of the distal section of the ulna, while the subject who received phosphate made a modest gain. This is outlined below.

Subject	Phosphate	Bone Density Change (per cent)
Robinson	no	-3.61
Kolb	no	-8.20
Bratcher	X	X
Diaz	X	X
McNeil	yes	+2.26

Distal Section of the Ulna, Final Ambulatory Period. During the final ambulatory period for these subjects, all of the men except one made some gains in bone density during ambulation as shown below:

Subject	Change in Bone Density during Last Ambulatory Period covered by Radiographs (per cent)
Robinson	+5.54
Kolb	+5.08
Bratcher	+3.18
Diaz	+7.22
McNeil	No ambulation data

Bone Density Changes in the Capitate, First 12-Week Bed Rest. Those who exercised during the first 12-week bed rest of this part of the study gained to different degrees in bone density of the diagonal section of

the capitate, while those who did not exercise experienced minor losses. See below.

Subject	Exercise	Bone Density Change (per cent)
Robinson	no	-1.24
Kolb	no	-6.61
Bratcher	yes	+5.27
Diaz	yes	+8.57
McNeil	yes	+1.12

Section of the Capitate, Second 12-Week Bed Rest. During the second 12-week bed rest when extra phosphate was fed to the first two men and no phosphate to the remaining three subjects, the men were not uniform as to the bone density changes. One man receiving phosphate supplementation gained and the other lost in bone density. Of the three who received no phosphate supplementation, one gained and two became lower in bone density. See the summary below:

Subject	Phosphate	Bone Density Change (per cent)
Robinson	yes	+2.92
Kolb	yes	-5.27
Bratcher	no	-7.31
Diaz	no	-9.67
McNeil	no	+5.95

Section of Capitate, Third Bed Rest, Six Weeks. Phosphate appeared to have had no effect upon bone density in this short bed rest, with all three subjects who participated becoming lower in this respect, whether they received the phosphate supplement or not.

Subject	Phosphate	Bone Density Change (per cent)
Robinson	no	-3.93
Kolb	no	-6.59
Bratcher	X	X
Diaz	X	X
McNeil	yes	-4.69

Section of Capitate, Final Ambulatory Period. During the final ambulatory period, all subjects except one gained in bone density during the short period covered. An exception was found in McNeil who left immediately before he was to have given his final radiograph.

Subject	Change in Bone Density during Last Ambulatory Period (per cent)
Robinson	+5.21
Kolb	+7.32
Bratcher	+2.39
Diaz	+8.19
McNeil	No ambulation data

TABLE XXV

CHANGES IN SECTIONS OF THE DISTAL RADIUS, DISTAL U

INTEGRATOR COUNTS DURING EXPERIMENTAL PE

SUBJECT: RANDALL ROBINSON

Position of Section	A 2/1/69	B 3/28/69	C 5/7/69	D 6/3/69	E 7/14/69	F 8/8/69	G
Distal Radius	4948.5	4837.0	4707.0	5005.0	4936.0	4830.0	
Distal Ulna	2178.5	2064.5	1853.5	2202.0	1921.0	1840.5	
Capitate	2396.0	2425.0	2000.0	2436.5	2058.5	1977.5	

SUBJECT: FRED KOLB

Distal Radius	3774.0	3170.0	3442.5	2793.5	3190.0	2903.5	
Distal Ulna	1681.5	1521.0	1608.5	1565.5	1500.0	1377.0	
Capitate	2255.5	2187.0	2106.5	2078.5	1995.5	1864.0	

SUBJECT: FRED BRATCHER

	Bed Rest with Exercise			Bed Rest- No Exercise		Re- ambulate	
Distal Radius	4278.0	4322.0	4533.5	4313.5	4261.0	4400.5	
Distal Ulna	1959.0	2056.0	2072.5	1905.0	1935.5	1997.0	
Capitate	2749.5	2940.5	2894.5	2716.5	2683.0	2747.0	

SUBJECT: ALFREDO DIAZ

Distal Radius	3195.0	3242.5	3402.0	3185.0	3104.5	3149.0	
Distal Ulna	1493.0	1605.5	1613.5	1619.5	1704.0	1827.0	
Capitate	2304.5	2523.0	2502.0	2284.5	2260.0	2445.0	

SUBJECT: GEORGE McNEIL

	Right Wrist and Lower Arm; Left Arm Amputated						
Distal Radius	4485.0	4531.0	4580.0	4446.5	4745.0	4881.5	
Distal Ulna	2204.5	2407.5	2248.5	2504.4	2207.5	2257.5	
Capitate	2778.0	2757.0	2809.0	2856.5	2976.0	2836.5	

TABLE XXV

SECTIONS OF THE DISTAL RADIUS, DISTAL ULNA, AND CAPITATE IN TERMS OF NTEGRATOR COUNTS DURING EXPERIMENTAL PHASES OF THE PROJECT

	C	D	E	F	G	H	Per Cent Change between Tests			
9	5/7/69	6/3/69	7/14/69	8/8/69	9/15/69	10/14/69	A to C	C to E	E to F	F to H
0	4707.0	5005.0	4936.0	4830.0	4702.0	4987.0	-4.88	+4.86	-2.14	+3.25
5	1853.5	2202.0	1921.0	1840.5	1920.5	1941.5	-1.49	+3.64	-3.61	+5.54
0	2000.0	2436.5	2058.5	1977.5	2034.0	2080.5	-1.24	+2.92	-3.93	+5.21
0	3442.5	2793.5	3190.0	2903.5	3189.0	3235.5	-8.78	-7.33	-8.98	+9.83
0	1608.5	1565.5	1500.0	1377.0	1385.5	1447.0	-4.34	-6.74	-8.20	+5.08
0	2105.5	2078.5	1995.5	1864.0	2220.0	2000.5	-6.61	-5.27	-6.59	+7.32

Exercise	Bed Rest- No Exercise		Re- ambulate						
0	4533.5	4313.5	4261.0	4400.5	X	X	+5.97	-6.01	+3.27	X
0	2072.5	1905.0	1935.5	1997.0	X	X	+5.79	-6.61	+3.18	X
5	2894.5	2716.5	2683.0	2747.0	X	X	+5.27	-7.31	+2.39	X
.5	3402.0	3185.0	3104.5	3149.0	X	X	+6.48	-8.74	+1.43	X
.5	1613.5	1619.5	1704.0	1827.0	X	X	+8.07	+5.61	+7.22	X
.0	2502.0	2284.5	2260.0	2445.0	X	X	+8.57	-9.67	+8.19	X

d Lower Arm; Left Arm Amputated										
.0	80.0	4446.5	4745.0	4881.5	X	X	+2.12	+3.60	+2.88	X
.5	2248.5	2504.4	2207.5	2257.5	X	X	+2.00	-1.82	+2.26	X
.0	2809.0	2856.5	2976.0	2836.5	X	X	+1.12	+5.95	-4.69	X

SECOND GROUP OF SUBJECTS

Changes in Bone Density

A new man, Robie Wilson, entered the study on May 7th, 1969, but he was not immediately placed in a test category. On June 16th he began to be fed a phosphate supplement while at bed rest, with this test continuing until September 8th.

Two other men entered this part of the study, and were radiographed for the first time by us on July 14th, 1969. These men were Roger Gieck and John Graham. They were placed on the phosphate test on August 25th and were continued with this daily dietary supplementation while at bed rest until November 10th. At the conclusion of the phosphate test, each of these three men continued with bed rest without any dietary supplementation, except that which was in their regular diet.

In summary, the plans for these three subjects, and the outcomes of their parts of the study are shown in short summaries and in the text material which follows through this part of the Report.

Changes in Multiple Sections of the Os Calcis in Terms of Integrator Counts during the First Bed Rest for the Second Group of Subjects, With and Without Phosphate Supplementation

Tables VI, VII, and VIII, which follow, give the data on multiple sections of the os calcis during a 12-week bed rest during which a phosphate supplement was fed to all three of the subjects under discussion.

Wilson received his initial radiographs for this bed rest on 6/3/69, with the bed rest beginning 6/16/69. His final radiograph of this period was on 9/15/69, with the bed rest closing on 9/8/69.

Gieck and Graham had their first radiographs made on 7/14/69. Their first bed rest extended from August 25, 1969 to November 10, 1969. The nearest times for x-rays which were available were August 8 and November 26, 1969.

Os Calcis, Initial Period. It was fortunate for the study that this second group of men each had an initial period of time for equilibration. Wilson had from 5/7/69 to 6/3/69, and the other two from 7/14/69 to 8/8/69. During this period, they showed the following changes in total bone density of the multiple sections of the os calcis:

Table A to B	Subject	Initial Bone Density Change (per cent)
VI	Wilson	+3.71
VII	Gieck	+4.04
VIII	Graham	+13.72

The gain during this period indicates improvement in the experimental diet in comparison with their previous diet.

Os Calcis, First Bed Rest for the Second Group of Participants. During the first bed rest in which the second group of men took part, they received the phosphate supplement throughout. The following summary shows the source of the data on this portion of the investigation, and the outcome in terms of per cent change in bone density during the period.

Table	Subject	Phosphate	Bone Density Change (per cent)
VI	Wilson	yes	+5.53
VII	Gieck	yes	-1.53
VIII	Graham	yes	+8.86

Os Calcis, Second Bed Rest for the Second Group of Participants. During the second bed rest for the second group of experimental subjects, the plan for this part of the investigation was to withhold the phosphate supplementation for all three men so that comparisons could be made at

close intervals of time. The difference in the bone density of the os calcis between the bed rest when the phosphate supplement was fed and that during which it was not provided is illustrated by the following brief summary:

Table	Subject	Phosphate	Bone Density Change (per cent)
VI	Wilson	no	-7.63
VII	Gieck	no	-5.95
VIII	Graham	no	-16.55

Os Calcis, Final Portion of Study Involving the Second Group of Subjects. The portion of ambulation of the three men under discussion which was covered by radiographs was of very short duration-- from 11/26/69 to 12/17/69. The data are summarized briefly as follows:

Table	Subject	Change in Bone Density during the Specified Period of Final Ambulation (per cent)
VI	Wilson	-0.99
VII	Gieck	+18.11
VIII	Graham	+13.50

TABLE V

CHANGES IN MULTIPLE SECTIONS OF THE OS CA

COUNTS DURING EXPERIMENTAL PHA

SUBJECT: ROBIE WILSON

Position of Section	Regular Tracing A 5/7/69	Regular Tracing B 6/3/69	Regular Tracing C 7/14/69	Regular Tracing D 8/8/69	Regular Tracing E 9/15/69	Regular Tracing F 10/14/69
2 mm up	9283	9432	9883	10691	9977	9970
1 mm up	9437	9641	9804	10732	10014	10003
CONVENTIONAL TRACE	9537	9738	9784	9872	9933	9616
1 mm down	9065	9147	9508	9824	9824	9678
2 mm down	8882	8839	9237	9867	9804	9632
3 mm down	8619	8527	8948	9418	9794	9474
4 mm down	8361	8471	8822	9467	9537	9444
5 mm down	8363	8336	8597	9245	9345	9196
6 mm down	8047	8206	8523	9101	9178	8819
7 mm down	8049	8062	8352	8888	8956	8539
8 mm down	7854	7922	8258	8795	8842	8483
9 mm down	7712	7753	8105	8478	8678	8242
10 mm down	7594	7662	7951	8175	8454	8114
11 mm down	7450	7554	7794	8100	8166	7865
12 mm down	7275	7413	7568	7951	7995	7707
13 mm down	7020	7186	7461	7585	7600	7480
14 mm down	6823	7017	7217	7259	7324	7182
15 mm down	6636	6815	6965	7002	7146	6929
16 mm down	6478	6584	6750	6814	7023	6687
17 mm down	6339	6540	6669	6789	6861	6466
18 mm down	6051	6396	6508	6539	6640	6384
19 mm down	5876	6306	6405	6385	6457	6209
20 mm down	5787	6219	6340	6213	6221	6013
21 mm down	5623	6113	6110	6145	6160	5875
22 mm down	5613	6002	5946	5928	6043	5686
23 mm down	5587	5941	5843	5894	5944	5519
24 mm down	5442	5822	5744	5787	5848	5403
25 mm down	5303	5679	5589	5697	5728	5328
26 mm down	5025	5572	5453	5497	5575	5181
27 mm down	5022	5436	5268	5450	5502	4981
28 mm down	4936	5369	5166	5241	5402	4889
29 mm down	4797	5301	5106	5120	5328	4863
30 mm down	4746	5143	4998	5087	5185	4784
31 mm down	4488	5032	4901	4973	5065	4668
32 mm down	4356	4798	4704	4863	4877	4424
33 mm down	4250	4629	4487	4518	4636	4132
34 mm down	4036	4239	4140	4184	4239	4065
35 mm down	3478	3721	3720	3751	3755	3572
36 mm down	2939	2926	2921	2974	2943	2880
Total	252,179	261,541	265,451	274,299	275,999	264,391

TABLE VI

IN MULTIPLE SECTIONS OF THE OS CALCIS IN TERMS OF INTEGRATOR COUNTS DURING EXPERIMENTAL PHASES OF THE PROJECT

gular acing C 14/69	Regular Tracing D 8/8/69	Regular Tracing E 9/15/69	Regular Tracing F 10/14/69	Regular Tracing G 11/26/69	Regular Tracing H 12/17/69	Per Cent Change between Tests			
						A to B	B to E	E to G	G to H
9883	10691	9977	9970	9351	9299	+1.60	+5.78	-6.27	-0.56
9804	10732	10014	10003	9417	9382	+2.16	+3.87	-5.96	-0.37
97[illegible]	9872	9933	9616	9367	9210	+2.11	+2.00	-5.70	-1.68
95[illegible]	9824	9824	9678	9204	9146	+0.90	+7.40	-6.31	-0.63
9237	9867	9804	9632	9141	9074	-0.48	+10.92	-6.76	-0.73
8948	9418	9794	9474	9089	8926	-1.07	+14.86	-7.20	-1.79
8822	9467	9537	9444	8660	8638	+1.31	+12.58	-9.20	-0.25
8597	9245	9345	9196	8485	8475	+0.28	+11.44	-9.20	-0.12
8529	9101	9178	8819	8366	8355	+1.98	+11.84	-8.85	-0.13
8352	8888	8956	8539	8232	8231	+0.16	+11.09	-8.08	-0.01
8258	8795	8842	8483	8091	8094	+0.86	+11.61	-8.49	+0.04
8105	8478	8678	8242	7976	7883	+0.53	+11.93	-8.09	-1.16
7951	8175	8454	8114	7855	7774	+0.90	+10.34	-7.09	-1.03
7794	8100	8166	7865	7654	7652	+1.40	+8.10	-6.27	-0.03
7568	7951	7995	7707	7469	7419	+1.90	+7.85	-6.58	-0.67
7461	7585	7600	7489	7272	7187	+2.36	+5.76	-4.32	-1.17
7217	7259	7324	7182	7046	6961	+2.84	+4.37	-3.80	-1.21
6965	7002	7146	6929	6846	6672	+2.70	+4.86	-4.20	-2.54
6750	6814	7023	6687	6630	6448	+1.64	+6.67	-5.60	-2.74
6669	6789	6861	6466	6466	6299	+3.17	+4.91	-7.21	-2.58
6508	6539	6640	6384	6244	6168	+5.73	+3.78	-5.96	-1.22
6405	6385	6457	6209	6113	6029	+7.32	+2.39	-5.33	-1.37
6340	6213	6221	6013	5977	5883	+7.46	+0.03	-5.53	-1.57
6110	6145	6160	5875	5777	5725	+8.71	+0.77	-6.22	-0.90
5946	5928	6043	5686	5578	5511	+6.93	+0.68	-7.69	-1.20
5843	5894	5944	5519	5523	5514	+6.34	+0.05	-7.08	-0.16
5744	5787	5848	5403	5331	5356	+6.98	+0.45	-8.84	+0.47
5[illegible]	5697	5728	5328	5178	5193	+7.09	+0.86	-9.60	+0.29
5[illegible]	5497	5575	5181	5043	5066	+10.88	+0.05	-9.54	+0.46
5268	5450	5502	4981	4850	4890	+8.24	+1.21	-11.85	+0.82
5166	5241	5402	4889	4728	4741	+8.77	+0.61	-12.48	+0.27
5106	5120	5328	4863	4628	4607	+10.51	+0.51	-13.14	-0.45
4998	5087	5185	4784	4547	4441	+8.36	+0.82	-12.30	-2.33
4901	4973	5065	4668	4342	4334	+12.12	+0.66	-14.27	-0.18
4704	4863	4877	4424	4295	4122	+10.15	+1.65	-11.93	-4.03
4487	4518	4636	4132	4076	3971	+8.92	+0.15	-12.08	-2.58
4140	4184	4239	4065	3909	3731	+5.03	±0.00	-10.14	-4.55
3720	3751	3755	3572	3441	3226	+6.99	+0.91	-8.36	-6.25
2921	2974	2943	2880	2756	2787	-0.44	+0.58	-6.35	+1.12
55,451	274,299	275,999	264,391	254,953	252,420	+3.71	+5.53	-7.63	-0.99

TABLE VI

CHANGES IN MULTIPLE SECTIONS OF THE QS CALCU

COUNTS DURING THE BED REST PHASE O

SUBJECT: ROGER GIECK

Position of Section	Regular Tracing A 7/14/69	Regular Tracing B 8/8/69	Regular Tracing C 9/15/69	Regular Tracing D 10/14/69	Regular Tracing E 11/26/69	Regular Tracing F 12/17/69	Reg Tra 2/
2 mm up	9900	9451	9450	9478	9416	9155	
1 mm up	9903	9487	9488	9422	9399	9155	
CONVENTIONAL TRACE	9872	9641	9748	9678	9543	9486	
1 mm down	9230	9039	9069	8993	8811	8542	
2 mm down	8847	8869	8866	8772	8599	8427	
3 mm down	7943	8771	8811	8616	8504	8311	
4 mm down	7924	8671	8700	8579	8375	8189	
5 mm down	7803	8541	8443	8411	8343	8099	
6 mm down	7711	8316	8239	8178	8122	7862	
7 mm down	7542	8062	8015	8002	7938	7825	
8 mm down	7217	7769	7677	7606	7634	7518	
9 mm down	6953	7410	7374	7381	7310	7066	
10 mm down	6646	6954	6967	6922	6903	6761	
11 mm down	6372	6695	6654	6660	6618	6449	
12 mm down	6057	6280	6331	6282	6261	6078	
13 mm down	5418	5856	5897	5860	5844	5779	
14 mm down	5297	5681	5690	5694	5622	5607	
15 mm down	5005	5463	5393	5398	5370	5531	
16 mm down	4985	5182	5219	5149	5129	5288	
17 mm down	4753	5067	5183	5029	4994	5099	
18 mm down	4699	4889	4911	4918	4860	4937	
19 mm down	4587	4781	4834	4738	4690	4784	
20 mm down	4499	4688	4942	4752	4603	4704	
21 mm down	4457	4564	4658	4636	4546	4658	
22 mm down	4311	4512	4540	4508	4454	4600	
23 mm down	4263	4497	4534	4488	4441	4524	
24 mm down	4202	4347	4359	4317	4283	4434	
25 mm down	4144	4236	4320	4290	4224	4407	
26 mm down	3993	4142	4166	4197	4108	4296	
27 mm down	3953	4037	4030	4058	4026	4234	
28 mm down	3714	3897	3942	3896	3876	4046	
29 mm down	3696	3762	3853	3723	3717	3870	
30 mm down	3517	3676	3656	3693	3638	3784	
31 mm down	3493	3605	3568	3577	3544	3689	
32 mm down	3234	3477	3471	3435	3372	3454	
33 mm down	3012	3287	3281	3258	3201	3337	
34 mm down	2819	2967	3006	2957	2935	3023	
35 mm down	2486	2552	2581	2510	2451	2508	
Total	214,457	223,121	223,866	222,061	219,704	219,516	206

TABLE VII

IN MULTIPLE SECTIONS OF THE OS CALCIS IN TERMS OF INTEGRATOR COUNTS DURING THE BED REST PHASE OF THE PROJECT

egular racing C /15/69	Regular Tracing D 10/14/69	Regular Tracing E 11/26/69	Regular Tracing F 12/17/69	Regular Tracing G 2/9/70	Regular Tracing H 3/18/70	Per Cent Change between Tests			
						A to B	B to E	E to G	G to H
9450	9478	9416	9155	9047	10129	-4.54	-0.37	-3.92	+11.96
9488	9422	9399	9155	9115	10141	-4.20	-0.93	-3.02	+11.26
[illegible]	9678	9543	9486	9461	10121	-2.34	-1.02	-0.86	+6.98
[illegible]	8993	8811	8542	8780	9619	-2.07	-2.52	-0.35	+9.56
8866	8772	8599	8427	8413	9345	+0.25	-3.04	-2.16	+11.08
8811	8616	8504	8311	8374	9284	+10.42	-3.04	-1.53	+10.87
8700	8579	8375	8189	8080	9172	+9.43	-3.41	-3.52	+13.51
8443	8411	8343	8099	8008	8982	+9.46	-2.32	-4.02	+12.16
8239	8178	8122	7862	7824	8863	+7.85	-2.33	-3.67	+13.28
8015	8002	7938	7825	7988	8739	+6.89	-1.54	+0.63	+9.40
7677	7606	7634	7518	7699	8458	+7.65	-1.74	+0.85	+9.86
7374	7381	7310	7066	7112	8062	+6.57	-1.35	-2.71	+13.36
6967	6922	6903	6761	6636	7562	+4.63	-0.73	-3.87	+13.95
6654	6660	6618	6449	6399	7192	+5.07	-1.15	-3.31	+12.39
6331	6282	6261	6078	5928	6845	+3.68	-0.30	-5.32	+15.47
5897	5860	5844	5779	5658	6460	+8.08	-0.20	-3.18	+14.17
5690	5694	5622	5607	5357	6156	+7.25	-1.04	-4.71	+14.92
5393	5398	5370	5531	5063	5964	+9.15	-1.70	-5.72	+17.80
5219	5149	5129	5288	4770	5838	+3.95	-1.02	-7.00	+22.39
5183	5029	4994	5099	4566	5650	+6.61	-1.44	-8.57	+23.74
4911	4918	4860	4937	4360	5499	+4.04	-0.59	-10.29	+26.12
4834	4738	4690	4784	4268	5356	+4.23	-1.90	-9.00	+25.49
4942	4752	4603	4704	4117	5304	+4.20	-1.81	-10.56	+28.83
4658	4636	4546	4658	4047	5234	+2.40	-0.39	-10.98	+29.33
4540	4508	4454	4600	3907	5237	+4.66	-1.28	-12.28	+34.04
4534	4488	4441	4524	3847	5131	+5.49	-1.24	-13.38	+33.38
4359	4317	4283	4434	3709	5041	+3.45	-1.47	-13.40	+35.91
[illegible]	4290	4224	4407	3679	4967	+2.22	-0.28	-12.90	+35.01
[illegible]	4197	4108	4296	3584	4781	+3.73	-0.82	-12.76	+33.40
4030	4058	4026	4234	3421	4715	+2.12	-0.27	-15.03	+37.82
3942	3896	3876	4046	3310	4556	+4.93	-0.54	-14.60	+37.64
3853	3723	3717	3870	3221	4377	+1.78	-1.20	-13.34	+35.89
3656	3693	3638	3784	3191	4251	+4.52	-1.03	-12.29	+33.22
3568	3577	3544	3689	3099	4015	+3.21	-1.69	-12.56	+29.56
3471	3435	3372	3454	2980	3747	+7.51	-3.02	-11.62	+25.74
3281	3258	3201	3337	2814	3505	+9.13	-2.62	-12.09	+24.55
3006	2957	2935	3023	2605	3199	+5.25	-1.08	-11.24	+22.80
2581	2510	2451	2508	2193	2563	+2.65	-3.96	-10.53	+16.87
23,866	222,061	219,704	219,516	206,630	244,060	+4.04	-1.53	-5.95	+18.11

TABLE VIII

CHANGES IN MULTIPLE SECTIONS OF THE OS CALCIS

COUNTS DURING THE BED REST PHASE O

SUBJECT: JOHN GRAHAM

Position of Section	Regular Tracing A 7/14/69	Regular Tracing B 8/8/69	Regular Tracing C 9/15/69	Regular Tracing D 10/14/69	Regular Tracing E 11/26/69	Regular Tracing F 12/17/69	Reg Tra 2/
2 mm up	7983	9565	9514	10008	9689	9300	
1 mm up	8022	9589	9636	10001	9463	9294	
CONVENTIONAL TRACE	9640	9980	9920	10001	9293	9265	
1 mm down	7500	8960	8900	9238	9170	8596	
2 mm down	7294	8741	8603	8948	9407	8284	
3 mm down	7109	8483	8411	8795	9153	7996	
4 mm down	7031	8378	8300	8678	9025	7932	
5 mm down	6912	8270	8037	8498	8838	7800	
6 mm down	6789	8068	8012	8288	8644	7716	
7 mm down	6745	7972	8002	8199	8639	7593	
8 mm down	6573	7828	7842	8054	8415	7465	
9 mm down	6438	7559	7627	7896	8233	7221	
10 mm down	6258	7389	7295	7561	7903	6907	
11 mm down	5963	6989	6974	7225	7505	6461	
12 mm down	5640	6670	6559	6809	7084	5818	
13 mm down	5266	6150	6146	6299	6586	5531	
14 mm down	4836	5483	5578	5763	5939	5028	
15 mm down	4596	5143	5202	5420	5618	4700	
16 mm down	4374	4919	5039	5211	5355	4449	
17 mm down	4241	4653	4829	4943	5157	4254	
18 mm down	4054	4516	4588	4730	4905	3991	
19 mm down	3785	4220	4321	4390	4626	3684	
20 mm down	3531	3872	4042	4133	4364	3435	
21 mm down	3393	3723	3847	3884	4154	3290	
22 mm down	3327	3614	3718	3738	4057	3214	
23 mm down	3276	3522	3563	3687	3909	3139	
24 mm down	3235	3467	3510	3626	3892	3078	
25 mm down	3181	3406	3444	3536	3785	2937	
26 mm down	3109	3289	3340	3474	3734	2828	
27 mm down	3058	3155	3251	3363	3624	2692	
28 mm down	2978	3107	3200	3229	3564	2631	
29 mm down	2945	3046	3113	3224	3481	2559	
30 mm down	2827	2892	3035	3074	3365	2442	
31 mm down	2662	2823	2863	2920	3134	2361	
32 mm down	2372	2534	2560	2576	2837	2062	
33 mm down	1883	2082	1998	2131	2349	1682	
Total	178,826	203,370	204,819	211,550	221,383	187,635	184,

TABLE VIII

S IN MULTIPLE SECTIONS OF THE OS CALCIS IN TERMS OF INTEGRATOR COUNTS DURING THE BED REST PHASE OF THE PROJECT

Regular Tracing C 9/15/69	Regular Tracing D 10/14/69	Regular Tracing E 11/26/69	Regular Tracing F 12/17/69	Regular Tracing G 2/9/70	Regular Tracing H 3/18/70	Per Cent Change between Tests			
						A to B	B to E	E to G	G to H
9514	10008	9689	9300	9123	10009	+19.82	+1.30	-5.84	+9.71
9636	10001	9463	9294	9257	9976	+19.53	-1.31	-2.18	+7.77
[illegible]0	10001	9293	9265	9319	9990	+3.53	-6.88	+0.26	+7.20
8900	9238	9170	8596	8406	9082	+19.47	+2.34	-8.33	+8.04
8603	8948	9407	8284	8131	8946	+19.84	+7.62	-13.56	+10.02
8411	8795	9153	7996	7878	8763	+19.33	+7.90	-13.93	+11.23
8300	8678	9025	7932	7787	8605	+19.16	+7.72	-13.72	+10.50
8037	8498	8838	7800	7643	8454	+19.65	+6.87	-13.52	+10.61
8012	8288	8644	7716	7480	8315	+18.84	+7.14	-13.46	+11.16
8002	8199	8639	7593	7392	8216	+18.19	+8.37	-14.43	+11.15
7842	8054	8415	7465	7204	8022	+19.09	+7.50	-14.39	+11.35
7627	7896	8233	7221	6984	7840	+17.41	+8.92	-15.17	+12.26
7295	7561	7903	6907	6741	7513	+18.07	+6.96	-14.70	+11.45
6974	7225	7505	6461	6409	7054	+17.21	+7.38	-14.60	+10.06
6559	6809	7084	5818	5984	6607	+18.26	+6.21	-15.53	+10.41
6146	6299	6586	5531	5586	6188	+16.79	+7.09	-15.18	+10.78
5578	5763	5939	5028	4996	5605	+13.38	+8.32	-15.88	+12.19
5202	5420	5618	4700	4506	5219	+11.90	+9.24	-19.79	+15.82
5039	5211	5355	4449	4318	5060	+12.46	+8.86	-19.36	+17.18
4829	4943	5157	4254	4215	4887	+9.71	+10.83	-18.27	+15.94
4588	4730	4905	3991	4024	4616	+11.40	+8.61	-17.96	+14.71
4321	4390	4626	3684	3693	4221	+11.49	+9.62	-20.17	+14.30
4042	4133	4364	3435	3448	3891	+9.66	+12.71	-20.99	+12.85
3847	3884	4154	3290	3273	3816	+9.72	+11.58	-21.21	+16.59
3718	3728	4057	3214	3150	3710	+8.63	+12.26	-22.36	+17.78
3563	3687	3909	3139	3076	3672	+7.51	+10.99	-21.31	+19.38
3510	3626	3892	3078	3027	3670	+7.17	+12.26	-22.22	+21.24
[illegible]	3536	3785	2937	2940	3548	+7.07	+11.13	-22.32	+20.68
3540	3474	3734	2828	2753	3464	+5.79	+13.53	-26.27	+25.83
3251	3363	3624	2692	2688	3389	+3.17	+14.86	-25.83	+26.08
3200	3229	3564	2631	2538	3370	+4.33	+14.71	-28.79	+32.78
3113	3224	3481	2559	2484	3250	+3.43	+14.28	-28.64	+30.84
3035	3074	3365	2442	2359	3088	+2.30	+16.35	-29.90	+30.90
2863	2920	3134	2361	2274	2903	+6.05	+11.02	-27.44	+27.66
2560	2576	2837	2062	1997	2597	+6.83	+11.96	-29.61	+30.04
1998	2131	2349	1682	1668	2137	+10.57	+12.82	-28.99	+28.12
204,819	211,550	221,383	187,635	184,751	209,693	+13.72	+8.86	-16.55	+13.50

Changes in Second Group of Subjects--

Hand and Wrist

Hand Phalanx 4/2, Initial Period. During the first period of the investigation when no experimental program had been undertaken by these three men, their hand phalanges 4/2 showed a considerable gain in bone density. It is not known by the authors of this report whether they exercised while standing, by the use of the Exer-Genie, or whether they exercised in any other manner. In any case, through this ambulatory period they gained in bone density of phalanx as follows:

Table	Subject	Bone Density Change in Multiple Sections of Hand Phalanx 4/2 (per cent)
XIV	Wilson	+11.59
XV	Gieck	+7.56
XVI	Graham	+13.26

Hand Phalanx 4/2, First Bed Rest. During the first 12-week bed rest for these subjects, when phosphate supplementation was fed, hand phalanx 4/2 showed some increase in each of the men, as shown below:

Table	Subject	Phosphate	Bone Density Change (per cent)
XIV	Wilson	yes	+13.51
XV	Gieck	yes	+15.14
XVI	Graham	yes	+15.80

Hand Phalanx 4/2, Second Bed Rest. During the second 12-week bed rest, when no extra phosphate was provided, the bone density change was in the opposite direction from that of the first bed rest when phosphate was fed, as was found with respect to the os calcis. The findings for this phalanx were the following:

Table	Subject	Phosphate	Bone Density Change (per cent)
XIV	Wilson	no	-8.34
XV	Gieck	no	-10.03
XVI	Graham	no	-8.44

Hand Phalanx 4/2, Final Portion of Study Involving the Second Group of Subjects. As mentioned above, the portion of the final ambulation period covered by radiographs was of very short duration. The bone density performance of the hand phalanx 4/2 was very irregular with respect to the three subjects, as might be expected, because the activity involving the hand in which each engaged was not recorded. The bone density changes of hand phalanx 4/2 are shown below:

Table	Subject	Bone Density Change in Hand Phalanx 4/2 during Portion of Final Ambulatory Period (per cent)
XIV	Wilson	+1.60
XV	Gieck	+14.42
XVI	Graham	+8.58

TABLE XIV

CHANGES IN MULTIPLE SECTIONS OF THE HAND PHALANX 4-2 IN TERMS OF INTEGRATOR COUNTS DURING THE BED REST PHASE OF THE PROJECT

SUBJECT: ROBIE WILSON

Position of Section	A 5/7/69	B 6/3/69	C 7/14/69	D 8/8/69	E 9/15/69	F 10/14/69	G 11/26/69	H 12/17/69	Per Cent Change between Tests			
									A to B	B to E	E to G	G to H
Proximal End of the Phalanx	860	961	1002	1051	1069	1016	1016	1025	+11.74	+11.24	-4.96	+0.89
1 mm up	744	811	911	905	942	891	881	890	+9.00	+16.15	-6.48	+1.02
2 mm up	732	805	833	867	880	854	836	852	+9.97	+9.32	-4.77	+1.91
3 mm up	664	757	768	812	820	811	786	795	+14.01	+8.32	-4.15	+1.14
4 mm up	665	738	785	790	775	774	772	786	+10.98	+5.01	-0.39	+1.81
5 mm up	651	739	768	799	791	779	771	790	+13.52	+7.04	-2.53	+2.46
6 mm up	656	734	768	787	805	779	765	770	+11.89	+9.67	-4.97	+0.65
7 mm up	653	737	759	805	820	788	775	789	+12.86	+11.26	-5.49	+1.81
8 mm up	644	729	745	774	817	772	763	778	+13.20	+12.07	-6.61	+1.96
9 mm up	630	721	757	777	805	763	741	752	+14.44	+11.65	-7.95	+1.48
10 mm up	619	693	711	762	803	782	731	750	+11.95	+15.87	-8.97	+2.60
11 mm up	609	673	707	753	802	764	712	705	+10.51	+19.17	-11.22	-0.98
12 mm up	580	674	704	733	776	745	680	692	+16.21	+15.13	-12.37	+1.76
13 mm up	577	658	677	723	749	724	676	689	+14.04	+13.83	-9.75	+1.92
14 mm up	576	638	682	715	729	720	664	673	+10.76	+14.26	-8.92	+1.36
15 mm up	577	636	671	699	734	706	644	682	+10.22	+15.41	-12.26	+5.90
16 mm up	569	636	668	704	733	718	653	668	+11.78	+15.25	-10.91	+2.30
17 mm up	592	664	673	722	766	732	671	689	+12.16	+15.36	-12.40	+2.68
18 mm up	600	663	674	723	791	762	673	678	+10.50	+19.31	-14.92	+0.74
19 mm up	590	660	682	725	776	747	670	674	+11.86	+17.58	-13.66	+0.60
20 mm up	602	676	686	728	761	737	673	685	+12.29	+12.57	-11.56	+1.78
21 mm up	583	655	687	720	746	729	659	660	+12.35	+13.89	-11.66	+0.15
22 mm up	590	643	680	712	742	722	677	688	+8.98	+15.40	-8.76	+1.62
23 mm up	465	469	583	588	603	597	556	567	+0.86	+28.57	-7.79	+1.98
Total	15,028	16,770	17,581	18,374	19,035	18,412	17,447	17,727	+11.59	+13.51	-8.34	+1.60

TABLE XV

CHANGES IN MULTIPLE SECTIONS OF THE HAND PHALANX 4-2 IN TERMS OF INTEGRATOR COUNTS DURING THE BED REST PHASE OF THE PROJECT

SUBJECT: ROGER GIECK

Position of Section	A 7/14/69	B 8/8/69	C 9/15/69	D 10/14/69	E 11/26/69	F 12/17/69	G 2/9/70	H 3/18/70	Per Cent Change between Tests			
									A to B	B to E	E to G	G to H
Proximal End of the Phalanx	922	936	1082	1087	1143	1076	1062	1196	+1.52	+22.11	-7.09	+12.62
1 mm up	752	848	937	921	984	977	889	1032	+12.76	+16.04	-9.65	+16.08
2 mm up	687	756	808	852	883	834	744	921	+10.04	+16.80	-15.74	+23.79
3 mm up	666	683	742	804	835	788	718	883	+2.55	+22.25	-14.01	+22.98
4 mm up	647	688	754	793	769	746	674	833	+6.34	+11.77	-12.35	+23.59
5 mm up	652	682	755	798	784	740	700	840	+4.60	+14.96	-10.71	+20.00
6 mm up	673	763	784	832	828	771	726	846	+13.37	+8.52	-12.32	+16.53
7 mm up	685	761	791	842	840	775	749	853	+11.09	+10.38	-10.83	+13.88
8 mm up	687	750	782	860	842	785	763	879	+9.17	+12.27	-9.38	+15.20
9 mm up	722	761	794	863	863	803	788	881	+5.40	+13.40	-8.69	+11.80
10 mm up	707	745	798	850	847	795	775	872	+5.37	+13.69	-8.50	+12.52
11 mm up	660	757	790	823	824	787	768	868	+14.70	+8.85	-6.80	+13.02
12 mm up	652	683	753	805	810	769	740	806	+4.75	+18.59	-8.64	+8.92
13 mm up	638	667	749	792	802	749	725	825	+4.54	+20.24	-9.60	+13.79
14 mm up	626	692	752	802	807	751	736	832	+10.54	+16.62	-8.80	+13.04
15 mm up	673	697	742	815	782	754	731	843	+3.57	+12.20	-6.52	+15.32
16 mm up	672	727	744	819	819	767	764	833	+8.18	+12.65	-6.71	+9.03
17 mm up	671	728	768	806	878	764	761	840	+8.49	+13.74	-8.09	+10.38
18 mm up	627	694	773	803	845	776	765	852	+10.69	+21.76	-9.47	+11.37
19 mm up	645	702	753	770	803	756	745	828	+8.84	+14.39	-7.22	+11.14
20 mm up	637	719	743	787	853	731	730	830	+12.87	+18.64	-14.42	+13.70
21 mm up	626	705	745	778	844	727	722	848	+12.62	+19.72	-14.45	+17.45
22 mm up	689	701	720	736	780	678	698	797	+1.74	+11.27	-10.51	+14.18
23 mm up	687	690	700	721	775	666	691	746	+0.44	+12.32	-10.84	+7.96
Total	16,303	17,535	[redacted]	19,759	20,190	18,765	18,164	[redacted]	+7.56	+15.14	-10.03	+14.42

TABLE XVI

CHANGES IN MULTIPLE SECTIONS OF THE HAND PHALANX 4-2 IN TERMS OF INTEGRATOR COUNTS DURING THE BED REST PHASE OF THE PROJECT

SUBJECT: JOHN GRAHAM

Position of Section	A 7/14/69	B 8/8/69	C 9/15/69	D 10/14/69	E 11/26/69	F 12/17/69	G 2/9/70	H 3/18/70	Per Cent Change between Tests			
									A to B	B to E	E to G	G to H
Proximal End of the Phalanx	943	1036	1105	1155	1192	1122	1037	1202	+9.86	+15.06	-13.00	+15.91
1 mm up	827	903	979	1068	1063	1010	936	1075	+9.19	+17.72	-11.95	+14.85
2 mm up	737	833	890	981	980	927	858	968	+13.02	+17.65	-12.45	+12.82
3 mm up	701	795	852	935	942	871	820	914	+13.41	+18.49	-12.95	+11.46
4 mm up	693	799	825	927	930	849	846	916	+15.30	+16.40	-9.03	+8.27
5 mm up	685	789	831	912	916	855	845	918	+15.18	+16.10	-7.75	+8.64
6 mm up	710	825	860	922	935	876	866	942	+16.34	+13.33	-7.38	+8.78
7 mm up	713	830	840	921	940	885	867	947	+16.41	+13.25	-7.76	+9.23
8 mm up	704	827	870	919	921	889	971	948	+17.47	+11.37	-5.43	+8.84
9 mm up	741	828	877	923	952	884	893	942	+11.74	+14.98	-6.20	+5.49
10 mm up	731	832	868	915	953	882	883	946	+13.82	+14.54	-7.34	+7.13
11 mm up	720	801	856	893	910	863	851	913	+11.25	+13.61	-6.48	+7.28
12 mm up	715	783	853	899	912	852	855	901	+9.51	+16.48	-6.25	+5.38
13 mm up	703	782	840	871	896	836	839	893	+11.24	+14.58	-6.36	+6.44
14 mm up	709	804	838	854	906	825	825	907	+13.40	+12.69	-8.94	+9.94
15 mm up	713	791	860	905	909	824	864	896	+10.94	+14.92	-4.95	+3.70
16 mm up	710	779	844	891	921	821	869	912	+9.72	+18.23	-5.65	+4.95
17 mm up	706	770	841	887	904	824	804	897	+9.06	+17.40	-11.06	+11.57
18 mm up	667	747	811	888	902	813	811	892	+11.99	+20.75	-10.09	+9.99
19 mm up	639	742	769	846	863	766	784	839	+16.12	+16.31	-9.15	+7.01
20 mm up	595	713	773	841	835	747	775	816	+19.83	+17.11	-10.78	+9.53
21 mm up	567	683	721	791	788	692	759	780	+20.46	+15.37	-3.68	+2.77
22 mm up	567	652	709	777	773	695	723	757	+14.99	+18.56	-6.47	+4.70
Total	16,196	18,344	19,512	20,921	21,243	19,608	19,451	21,121	+13.26	+15.80	-8.44	+8.58

Multiple Sections of Hand Phalanx 5/2 for the Second Group of Men in the Investigation

The second group of men taking part in the study which is being reported had a short initial period before they were placed on a test. There were minor changes in some of the bone density values during this period. The values in the initial pre-testing period are shown below for the hand phalanx 5/2.

Hand Phalanx 5/2, Initial Ambulatory Period. For the short interval of the initial period, changes in bone density were minor with the second group of men in the study. The following represents the bone density changes in phalanx 5/2, the second phalanx in the little finger:

Table	Subject	Bone Density Change (per cent)
XXII	Wilson	-5.57
XXIII	Gieck	+6.89
XXIV	Graham	+1.16

Hand Phalanx 5/2, First 12-Week Bed Rest. During the first 12-week bed rest, all three men of this second group of subjects were given a phosphate supplement. In spite of the favorable bone density response to this treatment which was noted in certain other anatomic areas, the hand

phalanx 5/2 was irregular in the direction of the bone density changes in the three men of this group as shown below:

Table	Subject	Phosphate	Bone Density Change (per cent)
XXII	Wilson	yes	-1.22
XXIII	Gieck	yes	-2.95
XXIV	Graham	yes	+2.16

Hand Phalanx 5/2, Second 12-Week Bed Rest. Again phalanx 5/2 showed no conformity in the way in which it performed with respect to bone density change during the second bed rest, when no phosphate supplementation and no exercise was included in the program. As has been emphasized, this bone site differs according to numerous factors related to its behavior, with differences in the diet or the type of activity for which each subject is responsible. The bone density changes in this case have been the following:

Table	Subject	Phosphate	Bone Density Change (per cent)
XXII	Wilson	no	+1.95
XXIII	Gieck	no	+2.12
XXIV	Graham	no	-14.68

Hand Phalanx 5/2, Final Measured Results during Ambulation. When the portion of reambulation was measured radiographically following

the last bed rest for this second experimenial group, again there was no conformity among the men, either concerning direction or amount of bone density change in this particular bone, as shown in this brief summary:

Table	Subject	Change in Bone Density during the Last Measured Ambulatory Period (per cent)
XXII	Wilson	+0.70
XXIII	Gieck	+2.16
XXIV	Graham	+10.10

TABLE XXII

CHANGES IN MULTIPLE SECTIONS OF HAND PHALANX 5-2 IN TERMS OF INTEGRATOR COUNTS DURING THE BED REST PHASE OF THE PROJECT

SUBJECT: ROBIE WILSON

Position of Section	A 5/7/69	B 6/3/69	C 7/14/69	D 8/8/69	E 9/15/69	F 10/14/69	G 11/26/69	H 12/17/69	Per Cent Change between Tests			
									A to B	B to E	E to G	G to H
Proximal End of the Phalanx	846	803	819	806	791	819	805	818	-5.08	-1.49	+1.77	+1.61
1 mm up	731	677	666	690	705	705	675	694	-7.39	+4.14	-4.26	+2.81
2 mm up	651	607	562	628	616	631	583	582	-6.76	+1.48	-5.36	-0.17
3 mm up	604	557	536	571	536	589	562	562	-7.78	-3.77	+4.85	±0.00
4 mm up	593	543	545	579	531	576	562	571	-8.43	-2.21	+5.84	+1.60
5 mm up	564	528	545	546	526	570	542	490	-6.38	-0.38	+3.04	-9.59
6 mm up	521	507	521	529	515	535	512	493	-2.69	+1.58	-0.58	-3.71
7 mm up	501	485	503	511	476	511	492	496	-3.19	-1.86	+3.36	+0.81
8 mm up	480	459	461	501	461	474	468	460	-4.38	+0.44	+1.52	-1.71
9 mm up	463	439	437	467	427	466	454	441	-5.18	-2.73	+6.32	-2.86
10 mm up	449	429	425	459	424	456	437	490	-4.45	-1.17	+3.07	+12.13
11 mm up	456	454	464	479	450	488	460	476	-0.44	-0.88	+2.22	+3.48
12 mm up	501	479	482	525	468	523	451	488	-4.39	-2.30	-3.63	+8.20
13 mm up	538	502	508	530	480	542	500	535	-6.69	-4.38	+4.17	+7.00
14 mm up	566	543	544	568	533	583	531	568	-4.06	-1.84	-0.38	+6.97
15 mm up	569	552	570	589	524	592	556	480	-2.99	-5.07	+6.11	-13.67
16 mm up	463	403	442	438	395	425	441	450	-12.96	-1.99	+11.65	+2.04
Total	9,496	8,967	9,030	9,416	8,858	9,485	9,031	9,094	-5.57	-1.22	+1.95	+0.70

TABLE XXIII

CHANGES IN MULTIPLE SECTIONS OF HAND PHALANX 5-2 IN TERMS OF INTEGRATOR COUNTS DURING THE BED REST PHASE OF THE PROJECT

SUBJECT: ROGER GIECK

Position of Section	A 7/14/69	B 8/8/69	C 9/15/69	D 10/14/69	E 11/26/69	F 12/17/69	G 2/9/70	H 3/18/70	Per Cent Change between Tests			
									A to B	B to E	E to G	G to H
Proximal End of the Phalanx	842	935	983	938	856	911	888	888	+11.05	-8.45	+3.74	±0.00
1 mm up	670	758	870	739	686	722	717	724	+13.13	-9.50	+4.52	+0.98
2 mm up	559	621	736	657	618	627	583	638	+11.09	-0.48	-5.66	+9.43
3 mm up	529	580	696	605	553	579	576	596	+9.64	-4.66	+4.16	+3.47
4 mm up	529	582	676	593	592	586	567	613	+10.02	+1.72	-4.22	+8.11
5 mm up	548	587	678	596	580	598	576	615	+7.12	-1.19	-0.69	+6.77
6 mm up	577	611	700	612	587	604	605	628	+5.89	-3.93	+3.07	+3.80
7 mm up	584	605	721	620	594	598	609	611	+3.60	-1.82	+2.53	+0.33
8 mm up	580	601	720	636	607	609	624	637	+3.62	+1.00	+2.80	+2.08
9 mm up	581	607	735	625	587	595	603	630	+4.48	-3.29	+2.73	+4.48
10 mm up	573	597	722	619	577	587	587	616	+4.19	-3.35	+1.73	+4.94
11 mm up	544	575	710	608	570	598	578	606	+5.70	-0.87	+1.40	+4.84
12 mm up	568	603	678	613	579	581	555	585	+6.16	-3.98	-4.15	+5.41
13 mm up	553	609	666	625	586	609	595	611	+10.13	-3.78	+1.54	+2.69
14 mm up	592	623	682	641	612	635	618	631	+5.24	-1.77	+0.98	+2.10
15 mm up	599	622	699	685	610	644	626	620	+5.68	-3.63	+2.62	-0.96
16 mm up	617	646	698	683	632	647	710	663	+4.70	-2.17	+12.34	-6.62
17 mm up	620	627	668	629	638	647	682	631	+1.13	+1.75	+6.90	-7.48
Total	10,605	11,400	13,038	11,724	11,064	11,377	11,299	11,543	+6.89	-2.95	+2.12	+2.16

TABLE XXIV

CHANGES IN MULTIPLE SECTIONS OF HAND PHALANX 5-2 IN TERMS OF INTEGRATOR COUNTS DURING THE BED REST PHASE OF THE PROJECT

SUBJECT: JOHN GRAHAM

Position of Section	A 7/14/69	B 8/8/69	C 9/15/69	D 10/14/69	E 11/26/69	F 12/17/69	G 2/9/70	H 3/18/70	Per Cent Change between Tests			
									A to B	B to E	E to G	G to H
Proximal End of the Phalanx	783	801	809	811	821	785	690	781	+2.30	+2.50	-15.96	+13.19
1 mm up	714	745	750	751	766	739	633	754	+4.34	+2.82	-17.36	+19.12
2 mm up	643	677	661	658	673	637	538	656	+5.29	-0.59	-20.06	+21.93
3 mm up	612	626	623	625	617	618	523	579	+2.29	-1.44	-15.24	+10.71
4 mm up	611	617	612	613	623	604	521	552	+0.98	+0.97	-16.37	+5.95
5 mm up	604	589	583	596	610	600	527	565	-2.48	+3.56	-13.61	+7.21
6 mm up	601	587	596	602	615	612	532	550	-2.33	+4.77	-13.50	+3.38
7 mm up	612	592	594	602	626	602	531	570	-3.27	+5.74	-15.18	+7.34
8 mm up	613	590	591	598	622	588	533	565	-3.75	+5.42	-14.31	+6.00
9 mm up	592	580	585	595	608	578	520	556	-2.03	+4.83	-14.47	+6.92
10 mm up	572	576	583	589	582	558	513	556	+0.70	+1.04	-11.86	+8.38
11 mm up	547	578	573	563	586	567	525	574	+5.67	+1.38	-10.41	+9.33
12 mm up	542	563	566	554	583	541	495	554	+3.87	+3.55	-15.09	+11.92
13 mm up	550	560	582	566	562	539	480	542	+1.82	+0.36	-14.59	+12.92
14 mm up	547	562	586	563	568	556	493	537	+2.74	+1.07	-13.20	+8.92
15 mm up	571	581	590	578	578	564	496	538	+1.75	-0.52	-14.19	+8.47
16 mm up	536	545	542	546	553	533	488	522	+1.68	+1.47	-11.75	+6.97
Total	10,250	10,369	10,426	10,410	10,593	10,221	9,038	9,951	+1.16	+2.16	-14.68	+10.10

Section of the Distal Radius for the Second Group of Men in the Investigation

Section of Distal End of Radius, Initial Ambulatory Period. For all the second group of experimental subjects, gains were made in the bone density of the distal end of the radius while they were ambulatory, before the first bed rest began. The following summary shows the changes in the three men:

Table	Subject	Bone Density Change (per cent)
XXVI	Wilson	+4.33
XXVI	Gieck	+8.64
XXVI	Graham	+5.13

Section at Distal End of Radius, First 12-Week Bed Rest. The one section which was evaluated across the distal end of the radius did not show consistent changes in bone density during the first 12-week bed rest of the second group of three men, as follows:

Table	Subject	Phosphate	Bone Density Change (per cent)
XXVI	Wilson	yes	+3.30
XXVI	Gieck	yes	-1.97
XXVI	Graham	yes	-9.73

Section of Distal End of Radius, Second 12-Week Bed Rest. As in the case of the first bed rest of this series when phosphate supplementation was not given, the bone density of a section which was scanned across the second 12-week bed rest of the series was not consistent in bone density changes as seen below:

Table	Subject	Phosphate	Bone Density Change (per cent)
XXVI	Wilson	no	-6.32
XXVI	Gieck	no	-1.24
XXVI	Graham	no	-2.07

Section of Distal End of Radius, Final Ambulatory Period. Ambulation frequently is not conducive to increases in bone density in the distal end of the radius. Our studies show that exercise of a type which effectuates muscular pull on the specific bone in question is the chief method of increasing bone density, as was shown in the work of Trueta[1,2] and associates. See summary which follows:

Table	Subject	Change in Bone Density During the Final Ambulatory Period (per cent)
XXVI	Wilson	+7.62
XXVI	Gieck	+7.07
XXVI	Graham	+13.96

Section of the Distal Ulna for the Second Group of Men in the Investigation

Section of Distal End of Ulna, Initial Ambulatory Period. The brief summary which follows shows that all three men in this part of the study gained to some extent in bone density of a section in the distal end of the ulna during the initial period, before the three men of this part of the study engaged in their first bed rest. This is shown in the following brief summary:

Table	Subject	Bone Density Change (per cent)
XXVI	Wilson	+4.50
XXVI	Gieck	+10.94
XXVI	Graham	+1.09

Section of Distal End of Ulna, First 12-Week Bed Rest. The data given below concerning the changes in bone density during this bed rest illustrate the fact that the lower arm makes no consistent gains or losses in bone density when a subject is ambulatory, unless he is exercising his lower arms in a consistent manner.

Table	Subject	Phosphate	Bone Density Change (per cent)
XXVI	Wilson	yes	-3.17
XXVI	Gieck	yes	+1.70
XXVI	Graham	yes	-10.33

Section of Distal End of Ulna, Second 12-Week Bed Rest. During the second 12-week bed rest, when neither phosphate supplementation nor exercise were included in the bed rest program, the bone density changes in the distal end of the ulna showed extreme inconsistency, as in the case with the distal radius. See below.

Table	Subject	Phosphate	Bone Density Change (per cent)
XXVI	Wilson	no	-6.32
XXVI	Gieck	no	-4.15
XXVI	Graham	no	-2.29

Section of Distal End of Ulna, Final Ambulatory Period. Undoubtedly none of the three subjects of this part of the investigation used his arms in a consistent manner throughout the study, or bone density changes would have been made in a consistent manner. Even when the men were no longer at bed rest, the lower ulna lost small amounts of bone density in two men, and gained appreciably in the third. See the following summary:

Table	Subject	Change in Bone Density During the Final Ambulatory Period (per cent)
XXVI	Wilson	+9.03
XXVI	Gieck	+3.64
XXVI	Graham	+6.25

Changes in the Capitate for the Second Group of Men in the Investigation

Throughout most of the radiographic measurements made in the bones of the hands and wrists of the men in this investigation, there was little consistency in the behavior of the bone density in the respective bones which were investigated. It is unfortunate that a record was not maintained for the motions of various parts of the body during bed rest and for the arm and hand activity, and the amount of walking during ambulation.

The bone density changes in the capitate during bed rest and ambulation are summarized briefly below. This matter will be considered further in the discussion which follows this section of the report.

Section of Capitate, Initial Ambulatory Period. Note: All of the following data come from Table XXVI.

Initial Ambulatory Period

Subject	Bone Density Change (per cent)
Wilson	-0.19
Gieck	+8.36
Graham	+15.56

First 12-Week Bed Rest

Subject	Phosphate	Bone Density Change (per cent)
Wilson	yes	+7.34
Gieck	yes	-6.56
Graham	yes	-13.04

Second 12-Week Bed Rest

Subject	Phosphate	Bone Density Change (per cent)
Wilson	no	-8.54
Gieck	no	-1.83
Graham	no	-2.41

Final Ambulatory Period

Subject	Change in Bone Density During the Final Ambulatory Period (per cent)
Wilson	+10.35
Gieck	+6.20
Graham	+13.16

TABLE XXV:

CHANGES IN SECTIONS OF THE DISTAL RADIUS, DISTAL U
INTEGRATOR COUNTS DURING EXPERIMENTAL P-

SUBJECT: ROBIE WILSON

Position of Section	A 5/7/69	B 6/3/69	C 7/14/69	D 8/8/69	E 9/15/69	F 10/14/69
Distal Radius	3209.5	3348.5	3325.5	3234.0	3459.0	3266.5
Distal Ulna	1478.5	1545.0	1492.0	1482.0	1496.0	1517.0
Capitate	2313.0	2308.5	2370.0	2342.0	2478.0	2357.5

SUBJECT: ROGER GIECK

Position of Section	A 7/14/69	B 8/8/69	C 9/15/69	D 10/14/69	E 11/26/69	F 12/17/69
Distal Radius	2964.5	3200.5	3073.5	3206.0	3157.0	3141.5
Distal Ulna	1270.5	1409.5	1395.5	1461.0	1433.5	1328.0
Capitate	1913.5	2073.5	1905.5	2005.0	1937.5	1929.5

SUBJECT: JOHN GRAHAM

Distal Radius	3136.5	3297.5	3214.5	3172.5	2976.5	2946.5
Distal Ulna	1518.0	1534.5	1538.0	1492.0	1376.0	1357.0
Capitate	1941.0	2243.0	2065.5	2031.5	1950.5	1919.0

TABLE XXVI

SECTIONS OF THE DISTAL RADIUS, DISTAL ULNA, AND CAPITATE IN TERMS OF INTEGRATOR COUNTS DURING EXPERIMENTAL PHASES OF THE PROJECT

C 7/14/69	D 8/8/69	E 9/15/69	F 10/14/69	G 11/26/69	H 12/17/69	Per Cent Change between Tests			
						A to B	B to E	E to G	G to H
[illegible]3229.5	3234.0	3459.0	3266.5	3240.5	3487.5	+4.33	+3.30	-6.32	+7.62
1492.0	1482.0	1496.0	1517.0	1401.5	1528.0	+4.50	-3.17	-6.32	+9.03
2370.0	2342.0	2478.0	2357.5	2266.5	2591.0	-0.19	+7.34	-8.54	+10.35

C 9/15/69	D 10/14/69	E 11/26/69	F 12/17/69	G 2/9/70	H 3/18/70	Per Cent Change between Tests			
						A to B	B to E	E to G	G to H
3073.5	3206.0	3157.0	3141.5	3118.0	3338.5	+8.64	-1.97	-1.24	+7.07
1395.5	1461.0	1433.5	1328.0	1374.0	1424.0	+10.94	+1.70	-4.15	+3.64
1905.5	2005.0	1937.5	1929.5	1902.0	2020.0	+8.36	-6.56	-1.83	+6.20

[illegible]3214.5	3172.5	2976.5	2946.5	2915.0	3322.0	+5.13	-9.73	-2.07	+13.96
1538.0	1492.0	1376.0	1357.0	1344.5	1428.5	+1.09	-10.33	-2.29	+6.25
2065.5	2031.5	1950.5	1919.0	1903.5	2154.0	+15.56	-13.04	-2.41	+13.16

DISCUSSION AND SUMMARY

It has been noted that, because of the fact that men taking part in this project entered at different times, and because of the further fact that the TWU team radiographed all of the men who were engaged in any aspect of the investigation each time they went to San Francisco, the beginning and the end of different aspects of bed rest units sometimes did not coincide with the first and last x-ray which is listed as marking the extent of certain bed rest periods.

SUMMARY I

Diagram I and the succeeding Diagrams show the times when the radiographs were taken for the designated men in reference to the Bed Rest Periods in which they engaged, together with their changes in bone density.

Changes in Bone Density of Multiple Sections of the Os Calcis Resulting from Exercise

A. Group with an Exercise Program during a Long Bed Rest. Only three men engaged in programmed exercise during a 12-week Bed Rest. In this situation outlined in Summary I, all three participants experienced modest gains in the total sections of the os calcis, ranging from +2.10 to +7.10 per cent.

B. Group which did not Exercise. When the same men did not perform exercise while they were recumbent in a Bed Rest of the same duration, they lost in bone density in percentages covering a relatively large range (from -1.44 to -21.67). See Summary I.

Changes in Bone Density of Multiple Sections of the Os Calcis from Addition of a Phosphate Supplement to the Diet

C. Group Receiving a Phosphate Supplement during a Bed Rest Period. Five men received a phosphate supplement during a 12-week Bed Rest, while one received this supplement during a period of one-half the duration. Four of the men experienced gains in the multiple section of the os calcis in percentage changes in the bone under discussion ranging from +0.58 to +8.86. One man receiving this phosphate supplement during the longer period had a low negative bone density change of -1.53 per cent.

The one man who received a phosphate supplement during the shorter Bed Rest Period had a positive os calcis bone density change of +2.07 per cent.

D. Same Group as C who did not Receive a Phosphate Supplement. The same men as in Section C took part in this phase of the study with no phosphate supplement, merely continuing with the Bed Rest. The Bed Rest itself was the overriding factor, with negative changes in bone

density throughout. The changes ranged from -4.94 to -16.55 per cent for the five men on the longer Bed Rest Periods, with the one man on the shorte Bed Rest losing 4.09 per cent. It must be remembered that the changes in bone density mentioned in Diagram I and Summary I, as in the remaining Diagrams and Summaries, relate to what happened from the beginning to the close of the Bed Rest Period under consideration.

E. Changes in Bone Density of Multiple Sections of the Os Calcis from Ambulation

A few of the subjects who took part in this study ambulated a short time before they went into a Bed Rest; but after they had received their first x-ray. There were three men in this category, as well as eight who had short periods of ambulation after the close of their last Bed Rest, with at least one radiograph made after they had re-ambulated.

Of the three men who had had a brief initial period of ambulation, all made small bone density gains (from 3.71 to 13.72 per cent).

Of the eight men who had at least a short period of final ambulation, gains in bone density of the overall multiple sections of the os calcis ranged from -0.99 to +26.34 per cent gain in comparison with the last radiograph made after their final Bed Rest Experience. See Diagrams I - 1, 2, 3, 4, 5, 6, 7, 8 for Bone Density Graphs.

SUMMARY I

EFFECT OF EXERCISE AND PHOSPHATE DURING BED REST ON BONE DENSITY OF MULTIPLE OS CALCIS SECTIONS

A. Exercise

	Change in Bone Density (Per Cent)
Bratcher (1st 12-week Bed Rest, A - C)	+2.33
Diaz (1st 12-week Bed Rest, A - C)	+2.10
McNeil (1st 12-week Bed Rest, A - C)	+7.10

B. No Exercise

Bratcher (2nd 12-week Bed Rest, C - E)	-1.44
Diaz (2nd 12-week Bed Rest, C - E)	-21.67
McNeil (2nd 12-week Bed Rest, C - E)	-4.09

C. Phosphate Supplement

Robinson (2nd 12-week Bed Rest, C - E)	+5.63
Kolb (2nd 12-week Bed Rest, C - E)	+0.58
Wilson (1st 12-week Bed Rest, B - E)	+5.53
Gieck (1st 12-week Bed Rest, B - E)	-1.53
Graham (1st 12-week Bed Rest, B - E)	+8.86
McNeil (Only 6-week Bed Rest with Phosphate, E - F)	+2.07

SUMMARY I, CONTINUED

EFFECT OF EXERCISE AND PHOSPHATE DURING BED REST ON BONE DENSITY OF MULTIPLE OS CALCIS SECTIONS

D. No Phosphate Supplement

	Change in Bone Density (Per Cent)
Robinson (1st 12-week Bed Rest, A - C)	-5.97
Kolb (1st 12-week Bed Rest, A - C)	-4.94
Wilson (2nd 12-week Bed Rest, E - G)	-7.63
Gieck (2nd 12-week Bed Rest, E - G)	-5.95
Graham (2nd 12-week Bed Rest, E - G)	-16.55
McNeil (Same as B above)	-4.09

E. Ambulation

Wilson (Initial Ambulation, A - B)	+3.71
Gieck (Initial Ambulation, A - B)	+4.04
Graham (Initial Ambulation, A - B)	+13.72
Robinson (Final Ambulation, F - H)	+3.41
Kolb (Final Ambulation, F - H)	+3.70
Bratcher (Final Ambulation, E - F)	+2.32
Diaz (Final Ambulation, E - F)	+26.34
McNeil (No Final Ambulation)	X
Wilson (Final Ambulation, G - H)	-0.99
Gieck (Final Ambulation, G - H)	+18.11
Graham (Final Ambulation, G - H)	+13.50

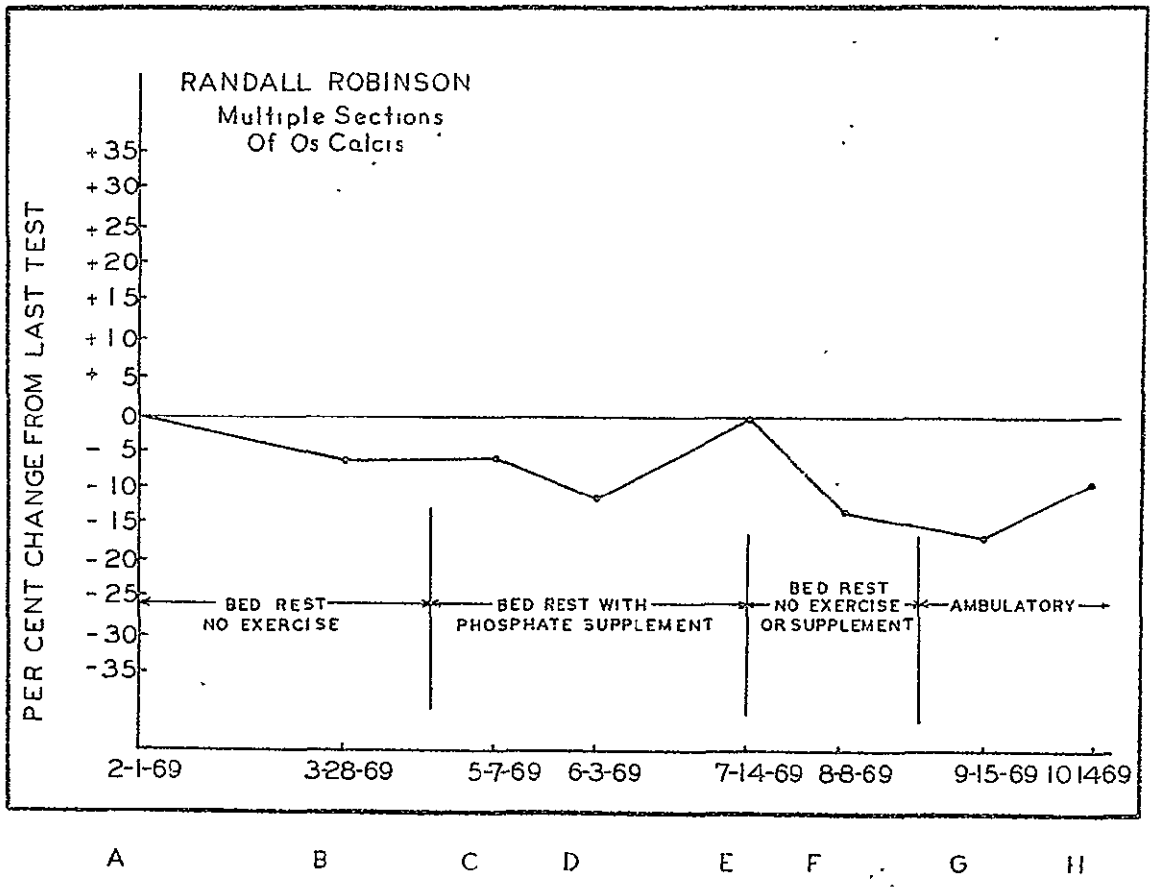

Diagram I - 1

Changes in Bone Density of the Multiple Os Calcis Sections of Robinson throughout his Participation in the Investigation. Per Cent Differences in Tables are Calculated from the Beginning to the Close of a Bed Rest or other Period.

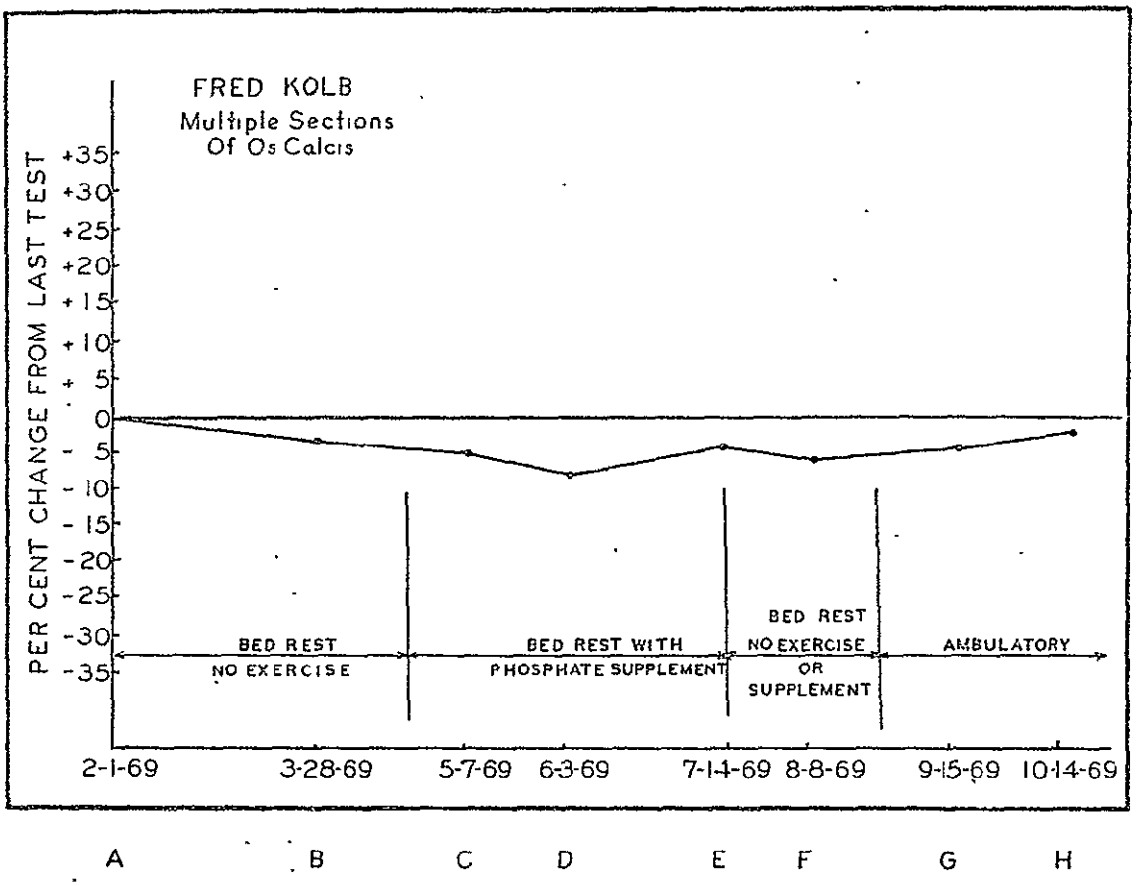

Diagram I - 2

Changes in Bone Density of the Multiple Os Calcis Sections of Kolb throughout his Participation in the Investigation. Per Cent Differences in Tables are Calculated from the Beginning to the Close of a Bed Rest or other Period.

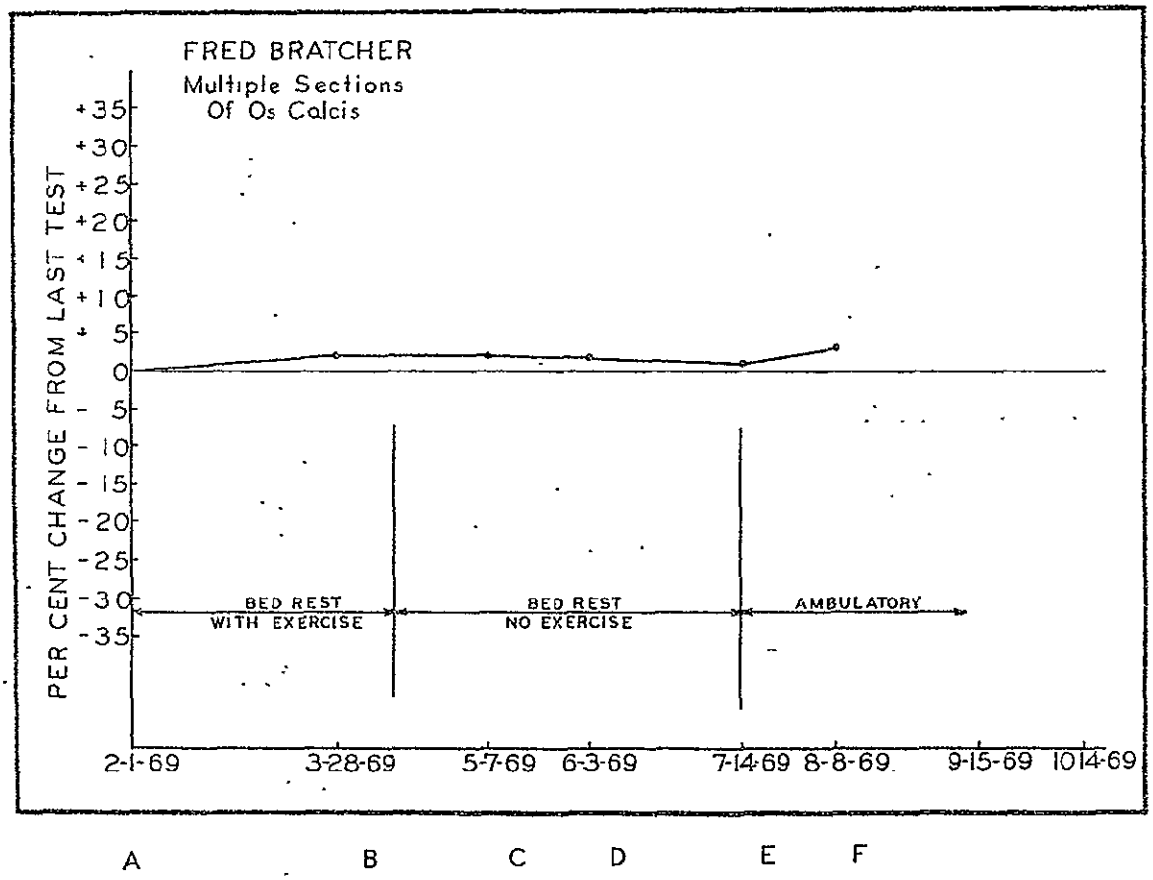

Diagram I - 3

Changes in Bone Density of the Multiple Os Calcis Sections of Bratcher throughout his Participation in the Investigation. Per Cent Differences in Tables are Calculated from the Beginning to the Close of a Bed Rest or other Period.

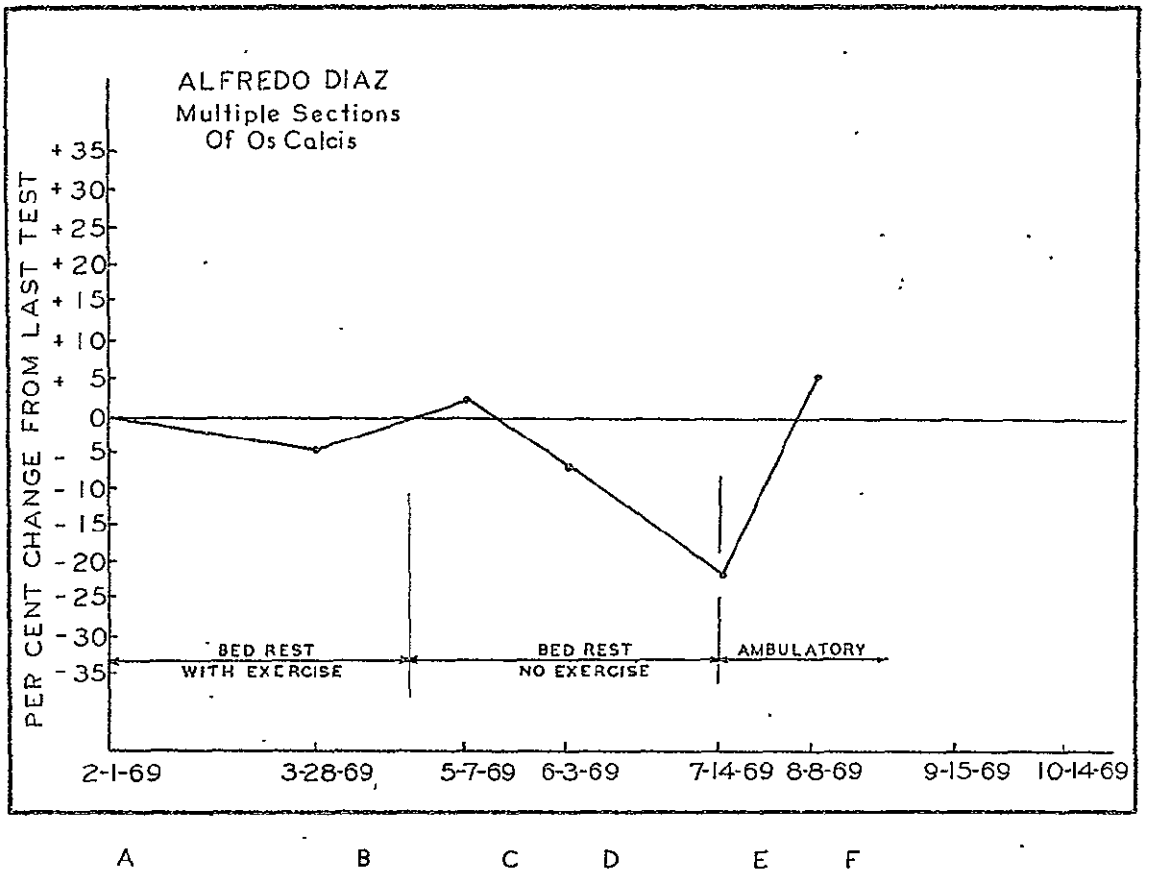

Diagram I - 4

Changes in Bone Density of the Multiple Os Calcis Sections of Diaz throughout his Participation in the Investigation. Per Cent Differences in Tables are Calculated from the Beginning to the Close of a Bed Rest or other Period.

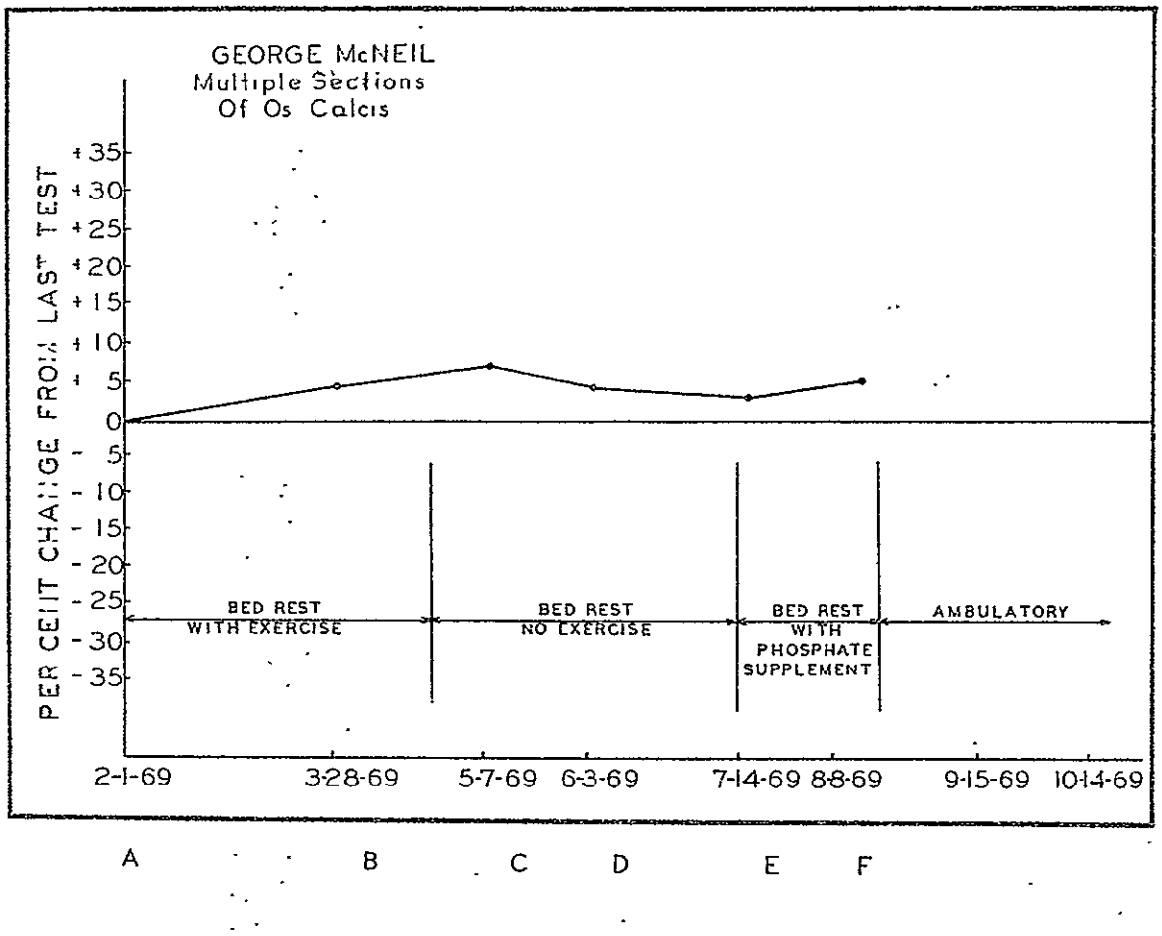

Diagram I - 5

Changes in Bone Density of the Multiple Os Calcis Sections of McNeil throughout his Participation in the Investigation. Per Cent Differences in Tables are Calculated from the Beginning to the Close of a Bed Rest or other Period.

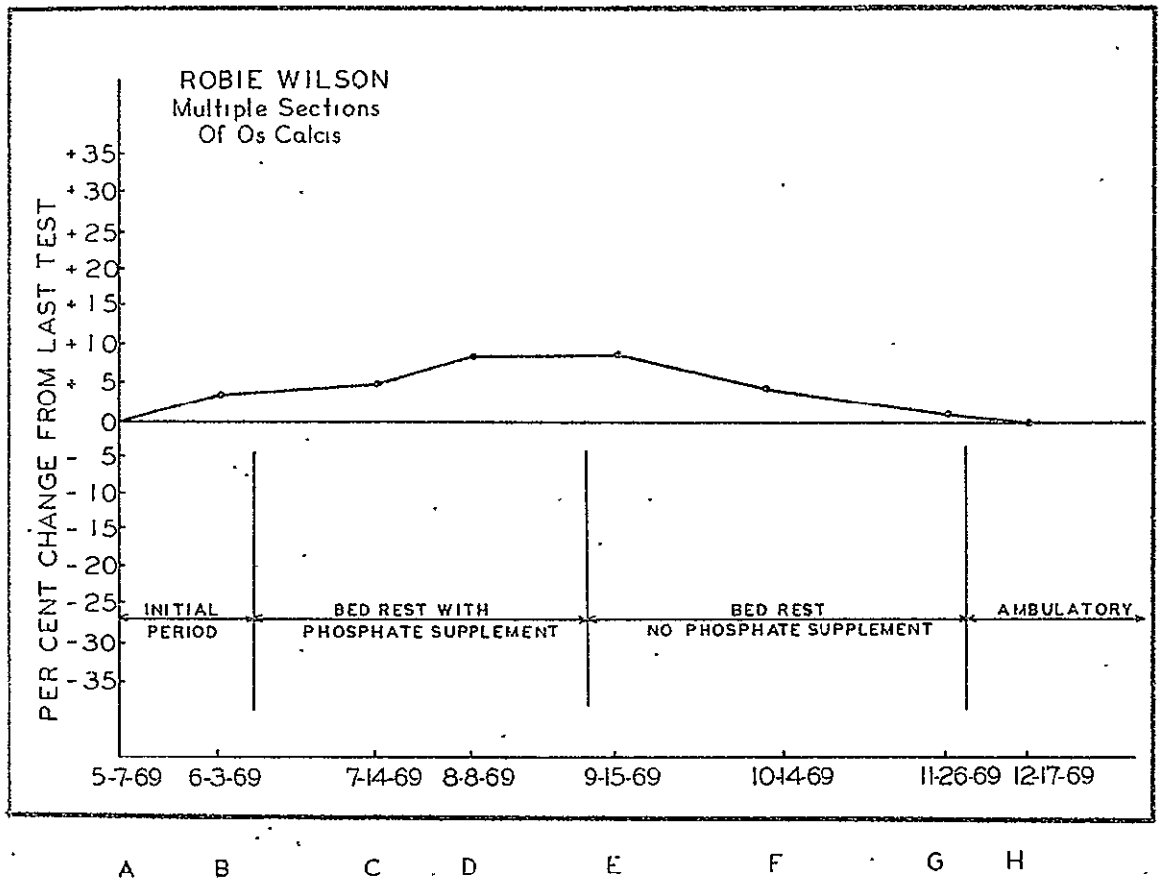

Diagram I - 6

Changes in Bone Density of the Multiple Os Calcis Sections of Wilson throughout his Participation in the Investigation. Per Cent Differences in Tables are Calculated from the Beginning to the Close of a Bed Rest or other Period.

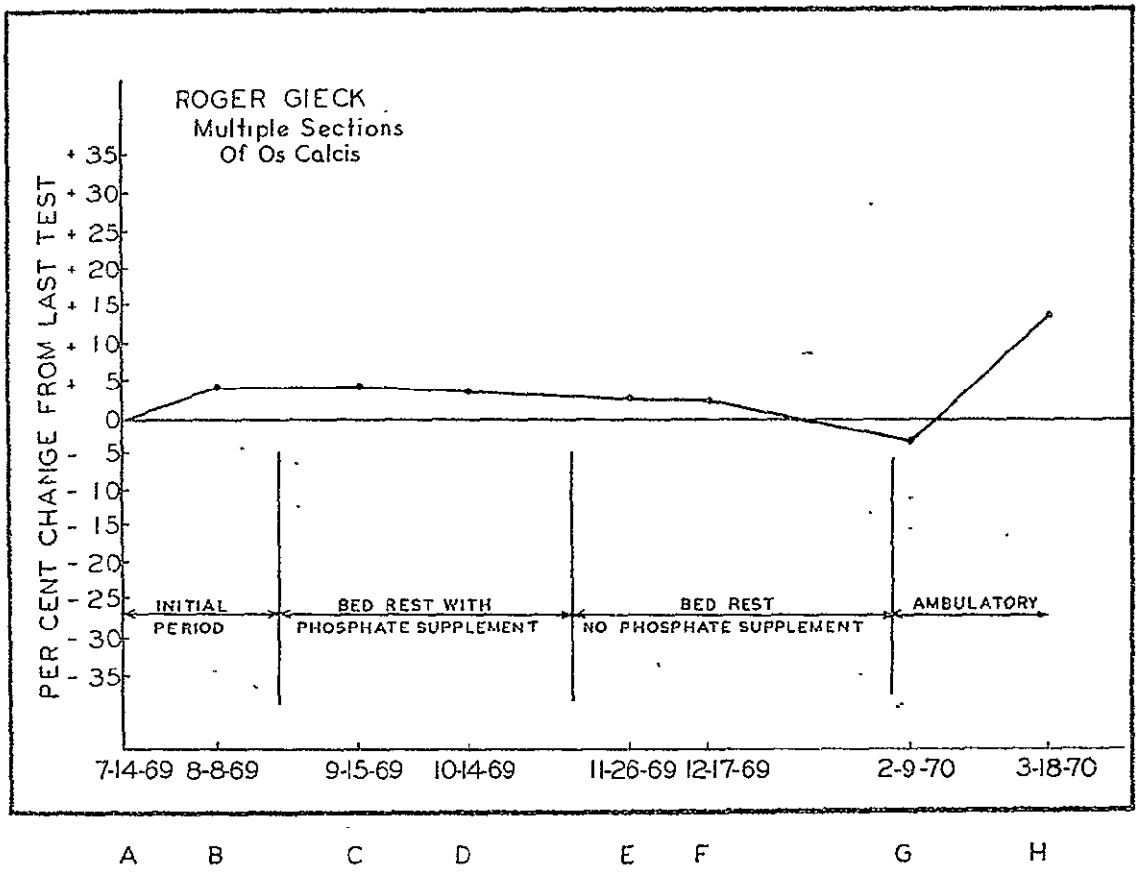

Diagram I - 7

Changes in Bone Density of the Multiple Os Calcis Sections of Gieck throughout his Participation in the Investigation. Per Cent Differences in Tables are Calculated from the Beginning to the Close of a Bed Rest or other Period.

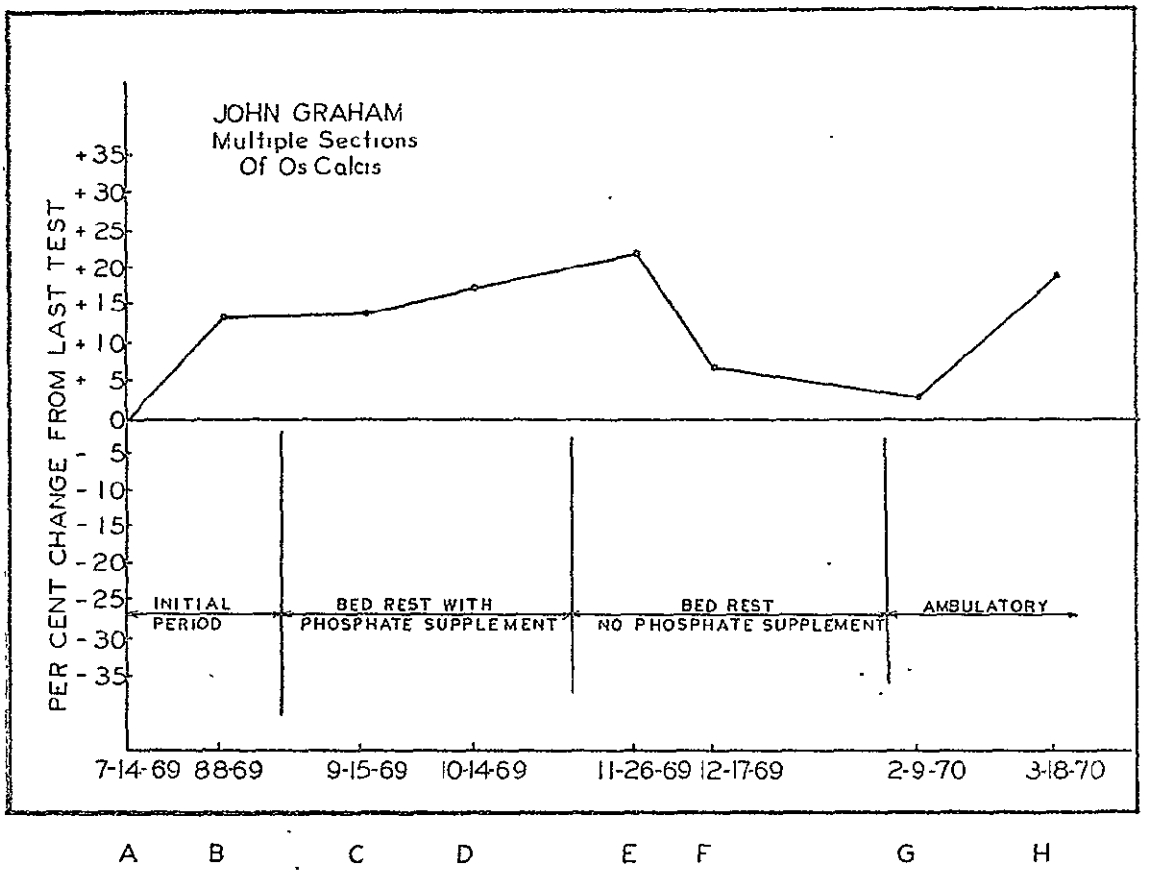

Diagram I - 8

Changes in Bone Density of the Multiple Os Calcis Sections of Graham throughout his Participation in the Investigation. Per Cent Differences in Tables are Calculated from the Beginning to the Close of a Bed Rest or other Period.

SUMMARY II

Changes in Bone Density of Multiple Sections of Phalanx 4/2 Resulting from Exercise

A. Group with Exercise Program during a Bed Rest Period. As noted under Summary I, only three men took part in a 12-week Bed Rest who exercised while recumbent. In this Bed Rest all three participants gained in bone density, with changes of +9.00, +9.28, and +9.73 per cent. It has been shown in T.W.U. Bed Rest studies that hand phalanx 4/2 tends to be actively involved in the use of the Exer-Genie, the exerciser used in this Project, if the exercise is carried out according to the T.W.U. program. See Diagrams II - 1 to 8.

B. Same Group as A who did not Exercise. When the men in Group A did not engage in an exercise program, all had negative changes in bone density in a 12-week Bed Rest, when little or no muscular pull on this bone took place. The bone density changes, all negative, ranged from -12.86 to -24.38 per cent.

Changes in Bone Density of Multiple Sections of Phalanx 4/2 Resulting from Addition of a Phosphate Supplement to the Diet

C. Group Receiving a Phosphate Supplement during a Bed Rest Period. Summary I has given the names of the four men who took part in

the longer Bed Rest when a phosphate supplement was included in the diet. One of the men gained less than one per cent in the multiple sections of hand phalanx 4/2, while others gained from +9.91 to +15.80 per cent.

The one man who received phosphate in the shorter Bed Rest lost less than one per cent during this period.

D. Same Group as C who did not Receive a Phosphate Supplement. The same men continued with another 12-week Bed Rest, with no phosphate supplement and no exercise. All subjects experienced further decreases in bone density in hand phalanx 4/2, with values ranging from -3.53 to -10.78 per cent.

E. Changes in Multiple Sections of Hand Phalanx 4/2 from Ambulation

As mentioned in the previous Summary, three men engaged in a short period of ambulation before they took part in the investigation proper. These men increased somewhat in bone density of the second phalanx in the fourth finger (from +7.56 to +13.26 per cent). The seven men who reambulated with a final radiograph after their period of ambulation gained in bone density in this bone in percentages ranging from +1.60 per cent to +24.34 per cent. Unfortunately the exercise in the fingers during this period was not recorded.

One man, who left on the date when he was booked to take a final x-ray, made it impossible to compute the change he had made in his final ambulation.

SUMMARY II

EFFECT OF EXERCISE AND PHOSPHATE DURING BED REST ON BONE DENSITY OF MULTIPLE SECTIONS OF PHALANX 4/2

A. Exercise

	Change in Bone Density (Per Cent)
Bratcher (1st 12-week Bed Rest, A - C)	+9.00
Diaz (1st 12-week Bed Rest, A - C)	+9.73
McNeil (1st 12-week Bed Rest, A - C)	+9.28

B. No Exercise

Bratcher (2nd 12-week Bed Rest, C - E)	-24.38
Diaz (2nd 12-week Bed Rest, C - E)	-20.03
McNeil (2nd 12-week Bed Rest, C - E)	-12.86

C. Phosphate Supplement

Robinson (2nd 12-week Bed Rest, C - E)	+0.17
Kolb (2nd 12-week Bed Rest, C - E)	+9.91
Wilson (1st 12-week Bed Rest, B - E)	+13.51
Gieck (1st 12-week Bed Rest, B - E)	+15.14
Graham (1st 12 week Bed Rest, B - E)	+15.80
McNeil (Only 6-week Bed Rest with Phosphate, E - F)	-0.12

SUMMARY II, CONTINUED

EFFECT OF EXERCISE AND PHOSPHATE DURING BED REST ON BONE DENSITY OF MULTIPLE SECTIONS OF PHALANX 4/2

D. No Phosphate Supplement

	Change in Bone Density (Per Cent)
Robinson (1st 12-week Bed Rest, A - C)	-3.53
Kolb (1st 12-week Bed Rest, A - C)	-10.78
Wilson (2nd 12-week Bed Rest, E - G)	-8.34
Gieck (2nd 12-week Bed Rest, E - G)	-10.03
Graham (2nd 12-week Bed Rest, E - G)	-8.44
McNeil (Same as B above)	-12.86

E. Ambulation

Wilson (Initial Ambulation, A - B)	+11.59
Gieck (Initial Ambulation, A - B)	+7.56
Graham (Initial Ambulation, A - B)	+13.26
Robinson (Final Ambulation, F - H)	+4.57
Kolb (Final Ambulation, F - H)	+9.71
Bratcher (Final Ambulation, E - F)	+18.43
Diaz (Final Ambulation, E - F)	+24.34
McNeil (No Final Ambulation)	X
Wilson (Final Ambulation, G - H)	+1.60
Gieck (Final Ambulation, G - H)	+14.42
Graham (Final Ambulation, G - H)	+8.58

SUMMARY III

Changes in Bone Density of Multiple Sections of Phalanx 5/2 Resulting from Exercise

A. Group with Exercise Program during a Bed Rest Period. As with other parts of the anatomy, only three men exercised during a 12-week Bed Rest Period, as shown in Summary I. It has been seen in T.W.U. Exercise Programs conducted during Bed Rest Periods, that hand phalanx 4/2 usually changes in bone density favorably, whereas this favorable response does not always appear universally in phalanx 5/2. Trials with the exerciser have shown that the second phalanx in the small finger is not involved in the exercise activity to the extent that is true of phalanx 4/2, and hence the muscle pull on the two bones is not similar. This is shown in the outcome of this trial, in which two men had negative (-2.73 and -6.33 per cent) and one had a positive change (+5.92 per cent) in bone density of this bone.

B. Same Group as those who Exercised in Group A, did not Exercise in Group B. Whereas they had mixed bone density results during the exercise period, they had uniform negative results ranging from -3.4 to -10.61 per cent when not exercising.

Changes in Bone Density of Multiple Sections of Phalanx 5/2 Resulting from the Addition of a Phosphate Supplement to the Diet

C. Group Receiving a Phosphate Supplement during a Bed Rest Period. It is shown in Summary III that five men received the phosphate supplement during a 12-week Bed Rest, with one subject receiving it during the shorter Bed Rest. Of the five receiving this supplement during the longer Bed Rest Period, four gained in bone density (+8.64, +6.63, +2.16, and +1.22 per cent), whereas the one on the shorter Bed Rest gained +4.11 per cent.

D. Same Group as those who Received a Phosphate Supplement in Group C, did not get a Phosphate Supplement in Group D. With no phosphate supplement during this 12-week Bed Rest, four of the men experienced positive bone density changes ranging from +1.95 to +5.66 per cent in phalanx 5/2. One of these men had a change in the opposite direction (-14.68).

The one man on the shorter Bed Rest made a bone density change of -3.45 per cent during this period with no phosphate supplement.

E. Changes in Multiple Sections of Hand Phalanx 5/2 during Ambulation

According to Summary III, 10 men had participated in ambulation, three initially before the Bed Rest Periods began, and seven finally, when the T.W.U. team was able to take an initial and final radiograph. Most of the ambulation periods were short because, as has been stated, we did not travel to the Hospital in San Francisco except when subjects participating in Bed Rest projects were to be radiographed, never solely for subjects who were ambulating.

Of the three men who underwent brief preliminary periods before they were placed in a Bed Rest, one changed +1.16 per cent in hand phalanx, one changed +6.89 per cent, and the third changed -5.57 per cent before they began participation in a bed rest.

Of the seven subjects who re-ambulated to a certain extent after their final bed rest, all gained in bone density by values which ranged from +0.70 to +14.25 per cent. See Diagrams II - 1, 2, 3, 4, 5; 6, 7, 8.

SUMMARY III

EFFECT OF EXERCISE AND PHOSPHATE DURING BED REST ON BONE DENSITY OF MULTIPLE SECTIONS OF PHALANX 5/2

A. Exercise

	Change in Bone Density (Per Cent)
Bratcher (1st 12-week Bed Rest, A - C)	+5.92
Diaz (1st 12-week Bed Rest, A - C)	-2.73
McNeil (1st 12-week Bed Rest, A - C)	-6.33

B. No Exercise

Bratcher (2nd 12-week Bed Rest, C - E)	-10.61
Diaz (2nd 12-week Bed Rest, C - E)	-9.26
McNeil (2nd 12-week Bed Rest, C - E)	-3.45

C. Phosphate Supplement

Robinson (2nd 12-week Bed Rest, C - E)	+8.64
Kolb (2nd 12-week Bed Rest, C - E)	+6.63
Wilson (1st 12-week Bed Rest, B - E)	+1.22
Gieck (1st 12-week Bed Rest, B - E)	-2.95
Graham (1st 12-week Bed Rest, B - E)	+2.16
McNeil (Only 6-week Bed Rest with Phosphate, E - F)	+4.11

SUMMARY III, CONTINUED

EFFECT OF EXERCISE AND PHOSPHATE DURING BED REST ON BONE DENSITY OF MULTIPLE SECTIONS OF PHALANX 5/2

D. No Phosphate Supplement

	Change in Bone Density (Per Cent)
Robinson (1st 12-week Bed Rest, A - C)	+5.66
Kolb (1st 12-week Bed Rest, A - C)	+3.32
Wilson (2nd 12-week Bed Rest, E - G)	+1.95
Gieck (2nd 12-week Bed Rest, E - G)	+2.12
Graham (2nd 12-week Bed Rest, E - G)	-14.68
McNeil (Same as B above)	-3.45

E. Ambulation

Wilson (Initial Ambulation, A - B)	-5.57
Gieck (Initial Ambulation, A - B)	+6.89
Graham (Initial Ambulation, A - B)	+1.16
Robinson (Final Ambulation, F - H).....	+14.25
Kolb (Final Ambulation, F - H)	+6.50
Bratcher (Final Ambulation, E - F).....	+4.67
Diaz (Final Ambulation, E - F)	+11.57
McNeil (No Final Ambulation)	X
Wilson (Final Ambulation, G - H)	+0.70
Gieck (Final Ambulation, G - H)	+2.16
Graham (Final Ambulation, G - H)	+10.10

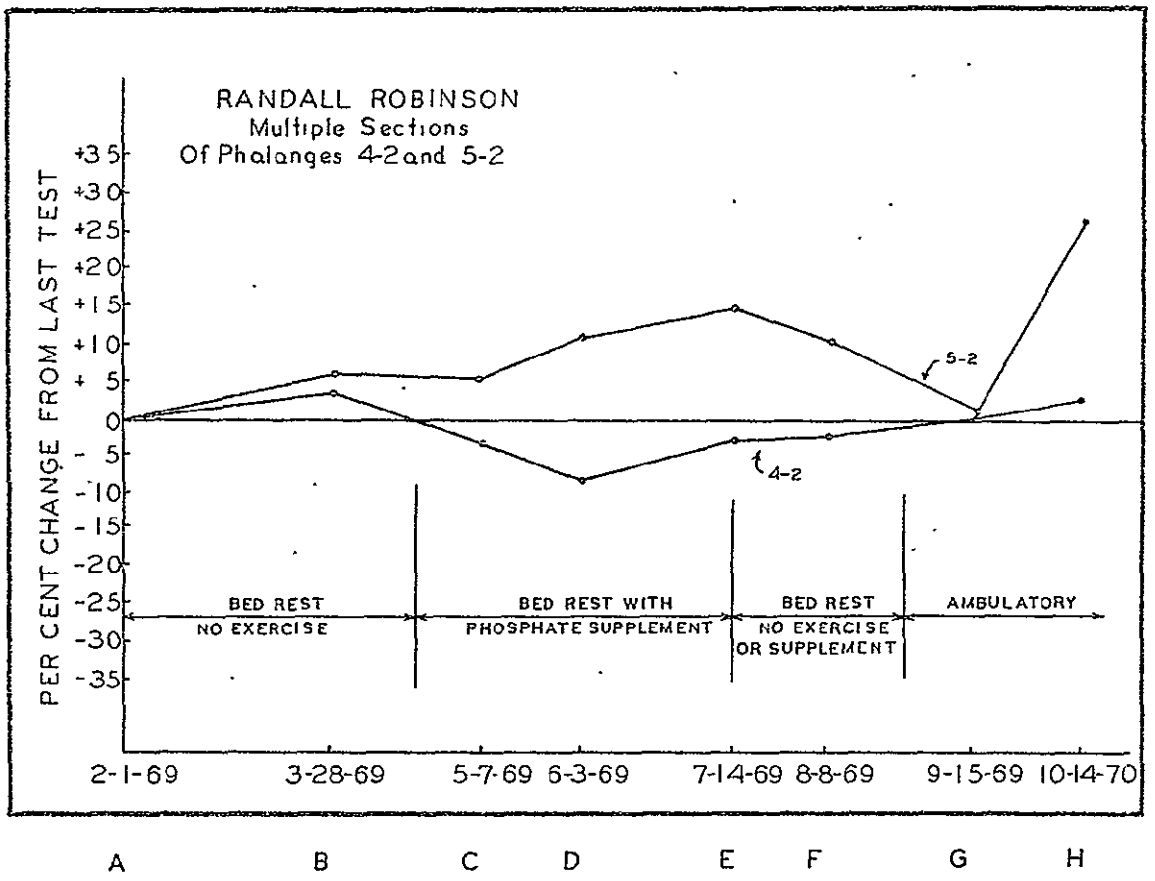

Diagram II - 1

Changes in Bone Density of the Multiple Hand Phalanges 4-2 and 5-2 Sections of Robinson. As in the Case of the Os Calcis Sections, Per Cent Differences in Tables are Calculated from the Beginning to the Close of a Bed Rest or other Period.

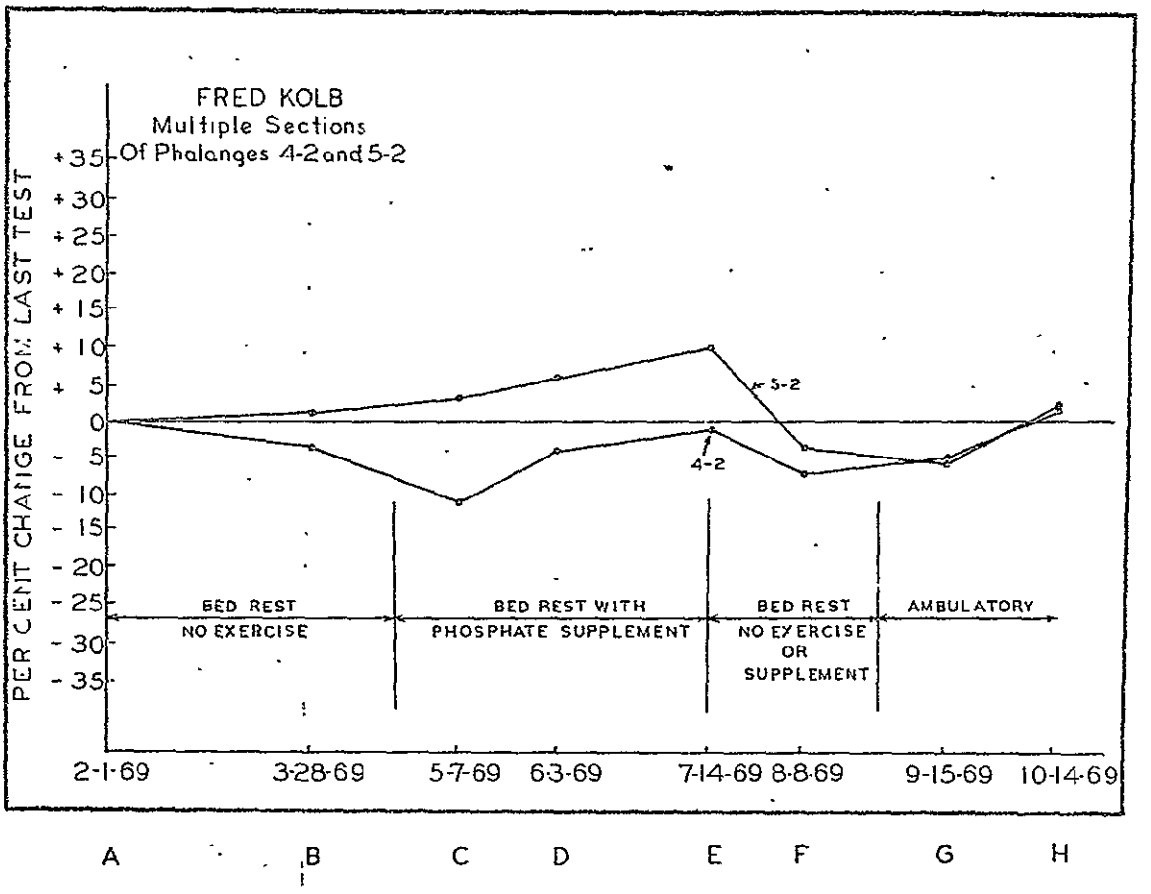

Diagram II - 2

Changes in Bone Density of the Multiple Hand Phalanges 4-2 and 5-2 Sections of Kolb. As in the Case of the Os Calcis Sections, Per Cent Differences in Tables are Calculated from the Beginning to the Close of a Bed Rest or other Period.

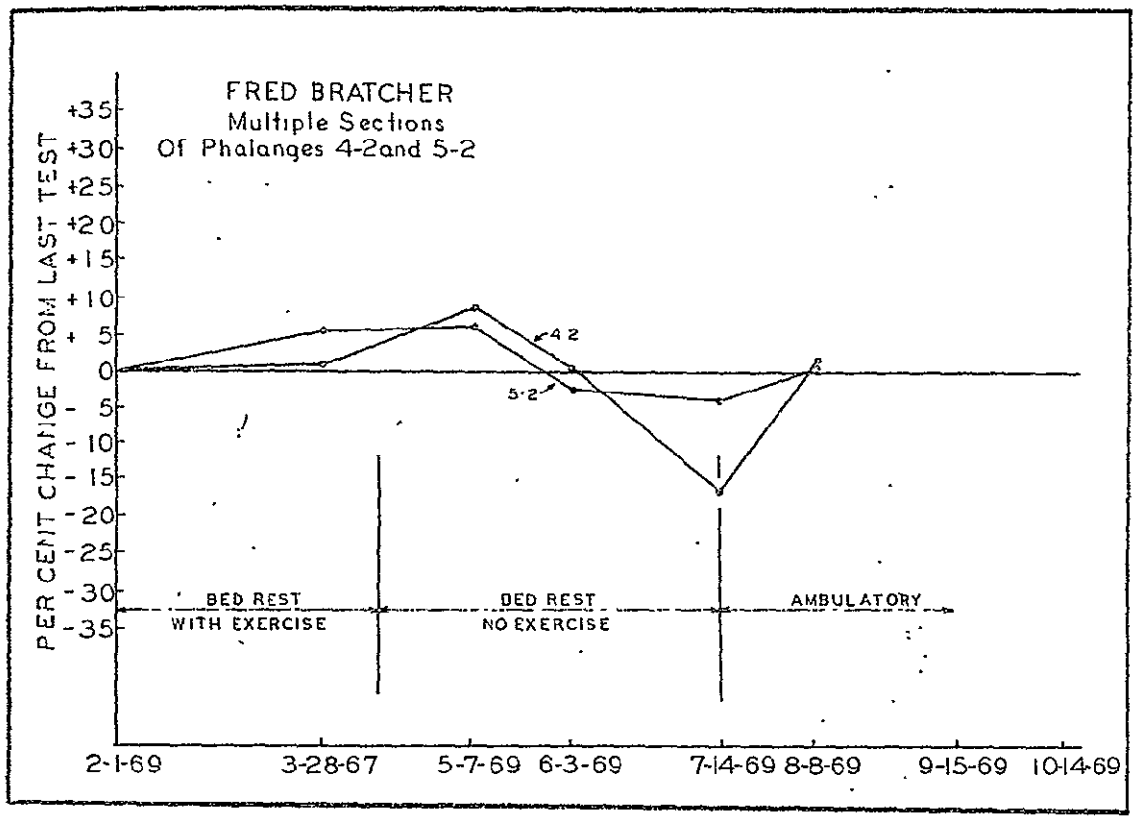

Diagram II - 3

Changes in Bone Density of the Multiple Hand Phalanges 4-2 and 5-2 Sections of Bratcher. As in the Case of the Os Calcis Sections, Per Cent Differences in Tables are Calculated from the Beginning to the Close of a Bed Rest or other Period.

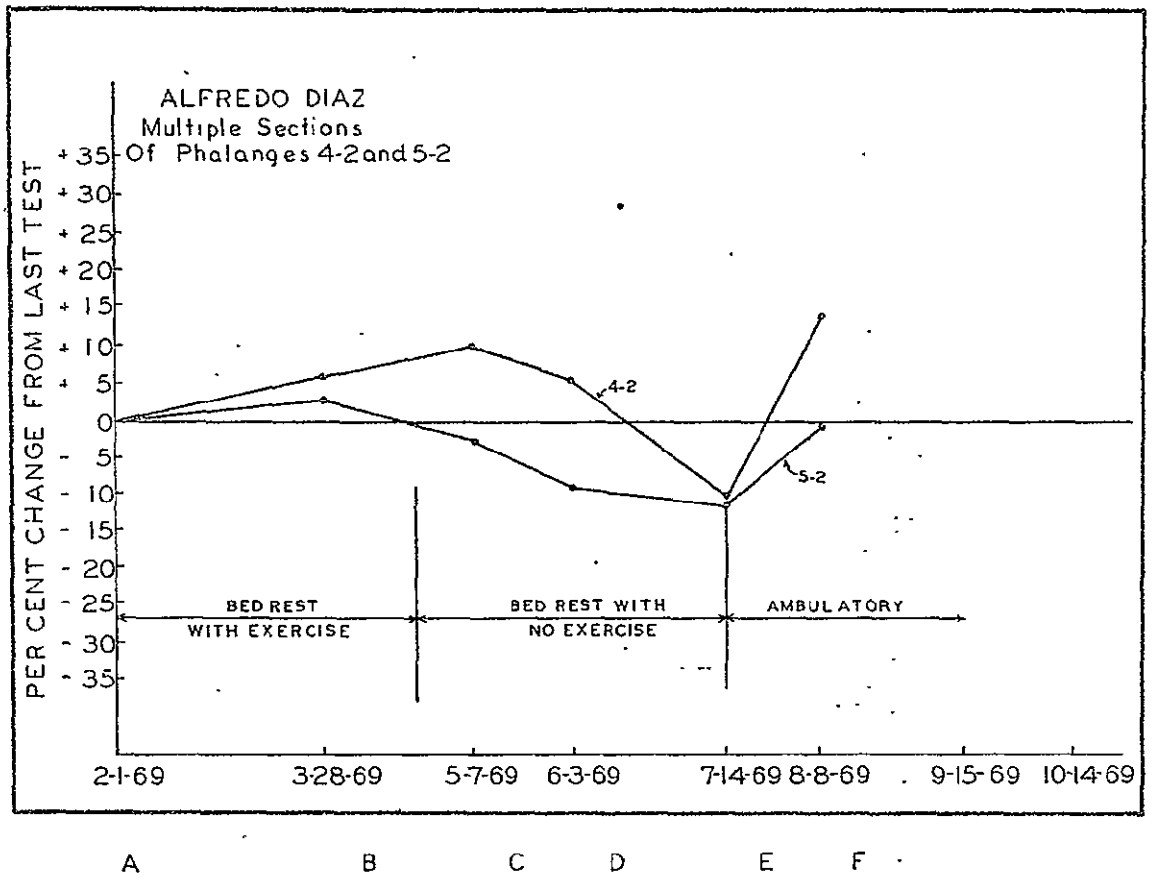

Diagram II - 4

Changes in Bone Density of the Multiple Hand Phalanges 4-2 and 5-2 Sections of Diaz. As in the Case of the Os Calcis Sections, Per Cent Differences in Tables are Calculated from the Beginning to the Close of a Bed Rest or other Period.

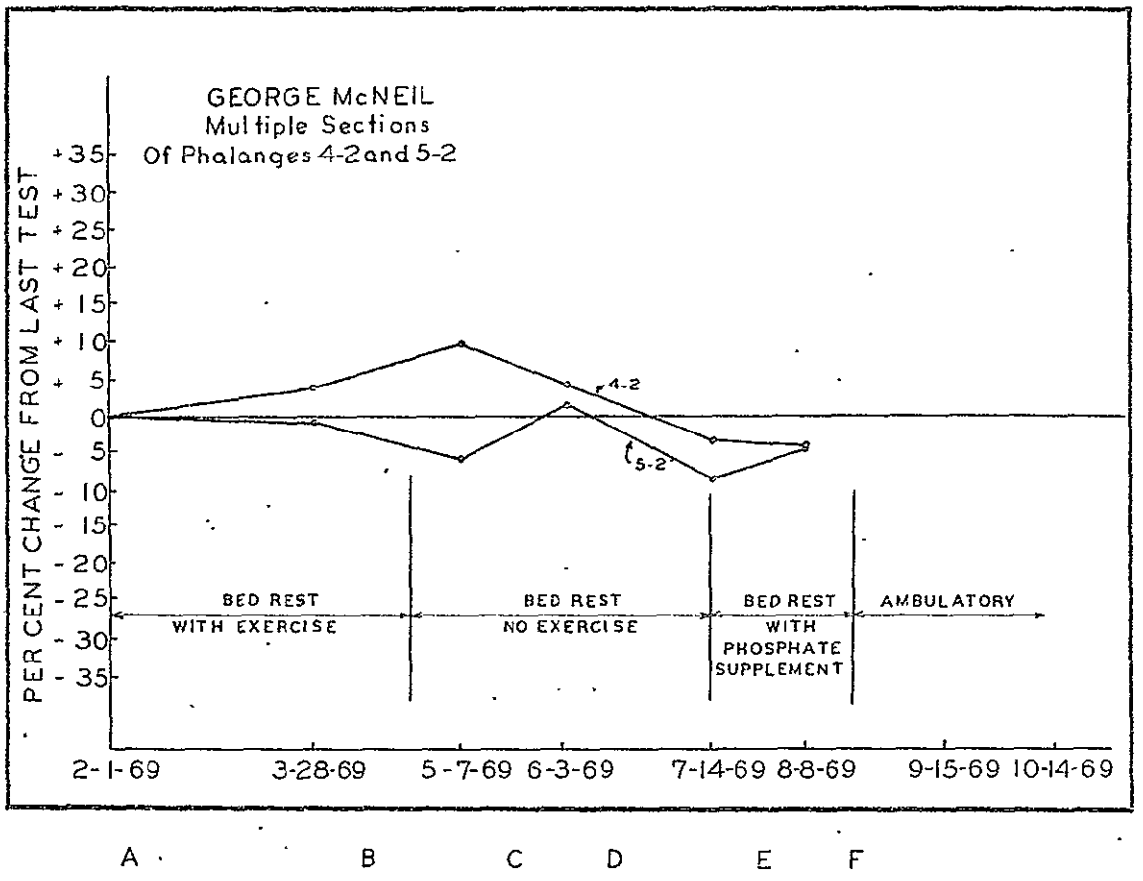

Diagram II - 5

Changes in Bone Density of the Multiple Hand Phalanges 4-2 and 5-2 Sections of McNeil. As in the Case of the Os Calcis Sections, Per Cent Differences in Tables are Calculated from the Beginning to the Close of a Bed Rest or other Period.

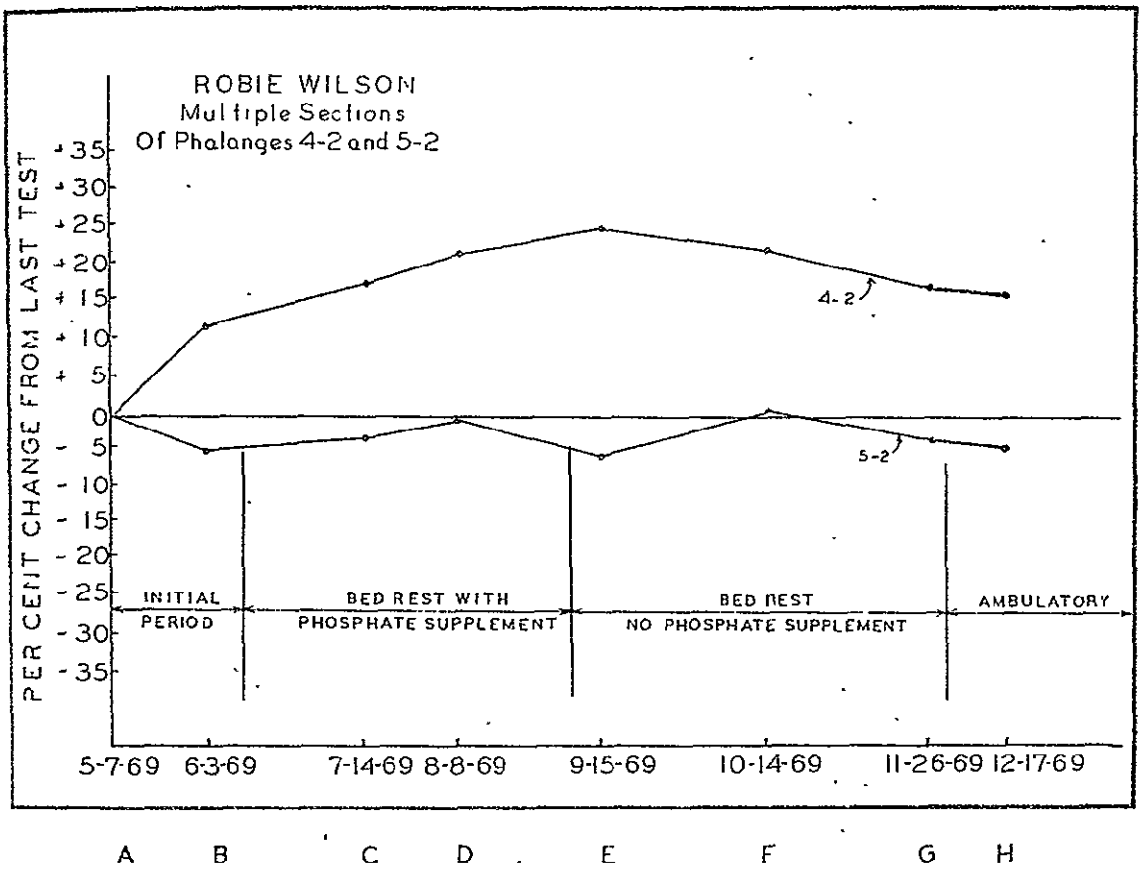

Diagram II - 6

Changes in Bone Density of the Multiple Hand Phalanges 4-2 and 5-2 Sections of Wilson. As in the Case of the Os Calcis Sections, Per Cent Differences in Tables are Calculated from the Beginning to the Close of a Bed Rest or other Period.

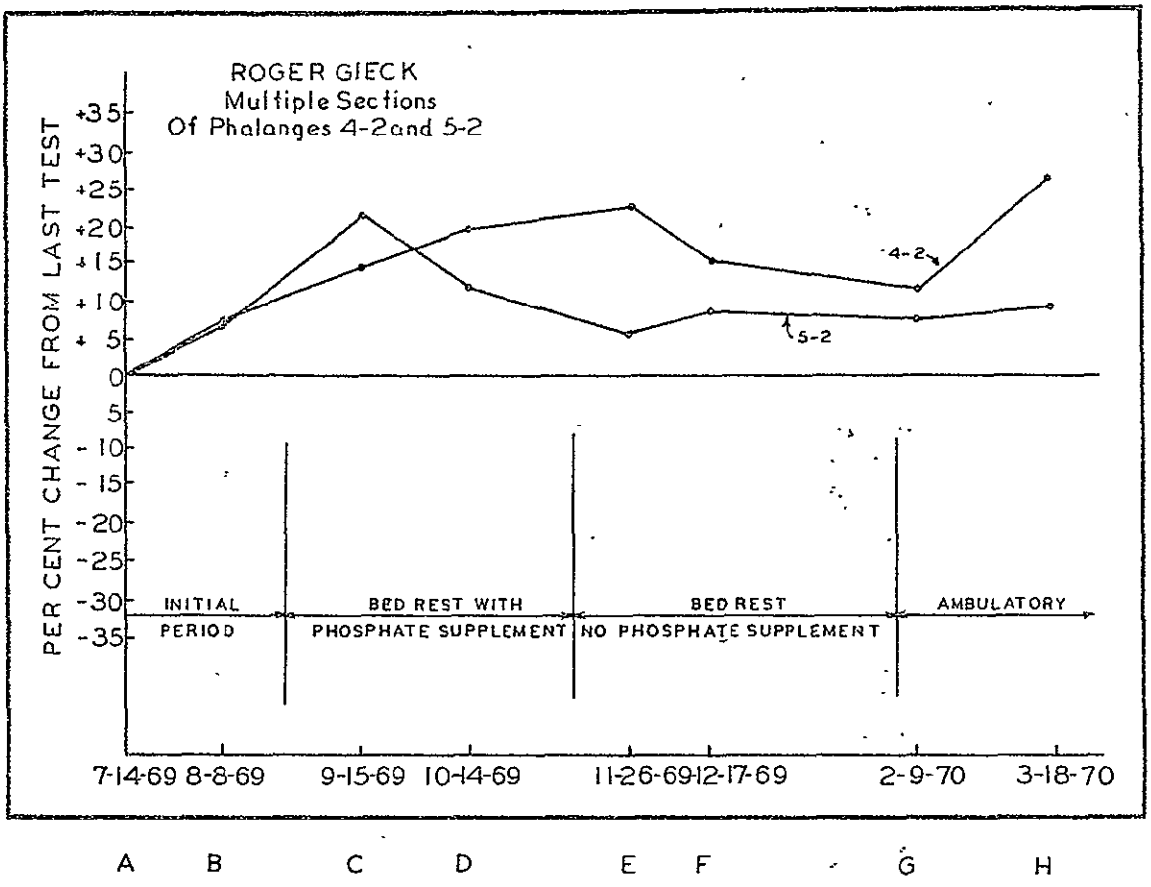

Diagram II - 7

Changes in Bone Density of the Multiple Hand Phalanges 4-2 and 5-2 Sections of Gieck. As in the Case of the Os Calcis Sections, Per Cent Differences in Tables are Calculated from the Beginning to the Close of a Bed Rest or other Period.

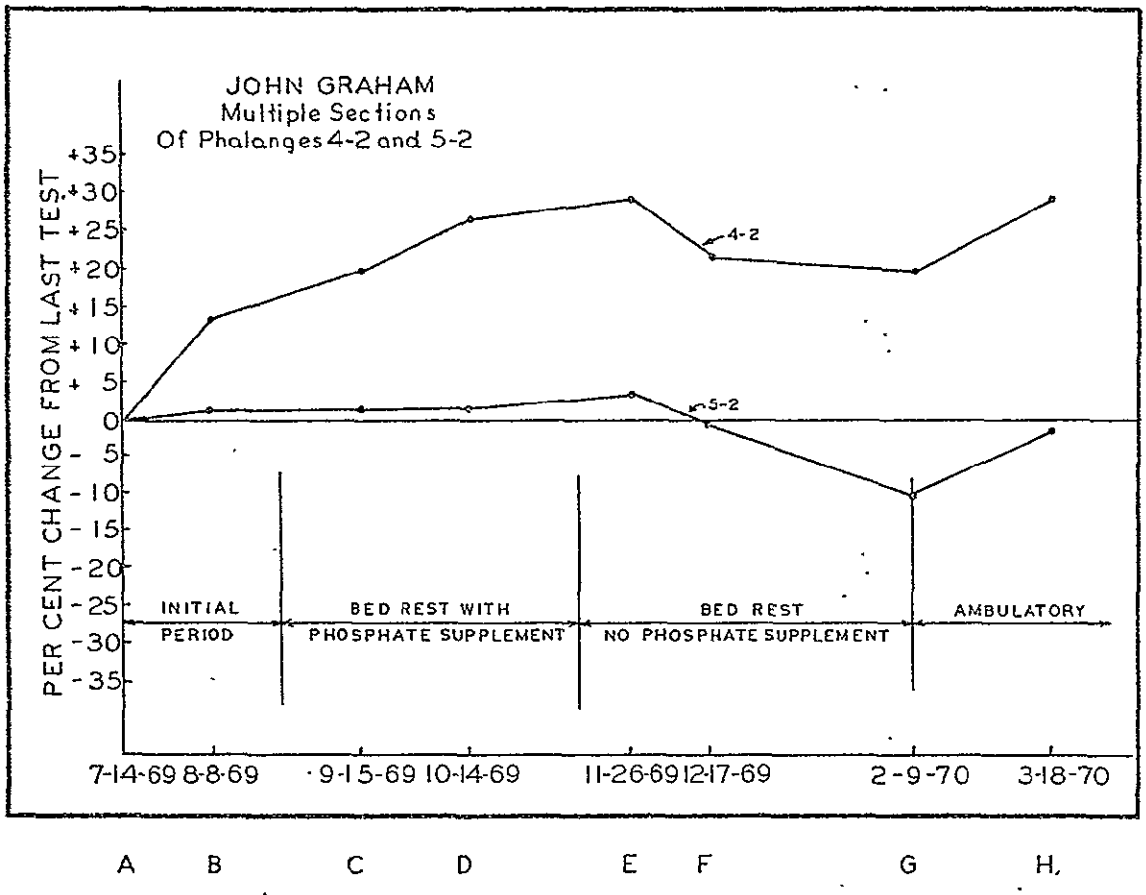

Diagram II - 8

Changes in Bone Density of the Multiple Hand Phalanges 4-2 and 5-2 Sections of Graham. As in the Case of the Os Calcis Sections, Per Cent Differences in Tables are Calculated from the Beginning to the Close of a Bed Rest or other Period.

SUMMARY IV

Changes in Bone Density of a Section at the Distal End of the Radius Resulting from Exercise and a Dietary Supplement

A. Group following an Exercise Program during a Long Bed Rest. The three men who exercised during a 12-week Bed Rest Period all made positive changes in a section across the distal end of the radius, as follows: +2.12; +5.97; +6.48 per cent.

B. Same Subjects as in Group A, who did not Engage in Exercise. The same men who had taken part in the exercise program of Group A changed to no exercise in a Bed Rest of the same duration. Two of the men lost in bone density, as would be expected (-6.01 and -8.74 per cent), while one made a slight gain (+3.60 per cent) in a section across the distal end of the radius.

C. Group receiving a Phosphate Supplement during Bed Rest. Five men took part in a 12-week Bed Rest during which a phosphate supplement was supplied in the daily diet.

One man received the phosphate supplement during the shorter Bed Rest.

The men consuming the extra phosphate in the longer Bed Rest varied in the direction of the bone density change, with two increasing in bone density (+3.30, and +4.86 per cent), and three decreasing (-1.97, -7.33, and -9.73 per cent). The man on the shorter Bed Rest made a minor bone density gain (+2.88 per cent).

D. Same Men as in Group C, who did not receive the Phosphate Supplement. The same men as in Group C who did not receive phosphate supplementation were uniform in changing in bone density of the distal radius in the negative direction. The extent of the changes were the following: -1.24; -2.07; -4.88; -6.32; and -8.78 per cent, respectively.

The one subject in the shorter Bed Rest made a minor gain in bone density during the "no Phosphate" period of +3.60 per cent.

E. Changes in Section in the Distal Radius during Ambulation. Summary IV shows that 10 subjects received adequate radiographs to have sections of the distal radius computed with reference to possible bone density changes in the distal ends of the radius.

All 10 men except one who left the study before the final x-ray was taken made positive changes in bone density in percentages ranging from +1.43 to +13.96 per cent.

SUMMARY IV

EFFECT OF EXERCISE AND PHOSPHATE DURING BED REST ON BONE DENSITY OF DISTAL RADIUS

A. Exercise

	Change in Bone Density (Per Cent)
Bratcher (1st 12-week Bed Rest, A - C)	+5.97
Diaz (1st 12-week Bed Rest, A - C)	+6.48
McNeil (1st 12-week Bed Rest, A - C)	+2.12

B. No Exercise

Bratcher (2nd 12-week Bed Rest, C - E)	-6.01
Diaz (2nd 12-week Bed Rest, C - E)	-8.74
McNeil (2nd 12-week Bed Rest, C - E)	+3.60

C. Phosphate Supplement

Robinson (2nd 12-week Bed Rest, C - E)	+4.86
Kolb (2nd 12-week Bed Rest, C - E)	-7.33
Wilson (1st 12-week Bed Rest, B - E)	+3.30
Gieck (1st 12-week Bed Rest, B - E)	-1.97
Graham (1st 12-week Bed Rest, B - E)	-9.73
McNeil (Only 6-week Bed Rest with Phosphate, E - F)	+2.88

SUMMARY IV, CONTINUED

EFFECT OF EXERCISE AND PHOSPHATE DURING BED REST ON BONE DENSITY OF DISTAL RADIUS

D. No Phosphate Supplement

	Change in Bone Density (Per Cent)
Robinson (1st 12-week Bed Rest, A - C)	-4.88
Kolb (1st 12-week Bed Rest, A - C)	-8.78
Wilson (2nd 12-week Bed Rest, E - G)	-6.32
Gieck (2nd 12-week Bed Rest, E - G)	-1.24
Graham (2nd 12-week Bed Rest, E - G)	-2.07
McNeil (Same as B above)	+3.60

E. Ambulation

Wilson (Initial Ambulation, A - B)	+4.33
Gieck (Initial Ambulation, A - B)	+8.64
Graham (Initial Ambulation, A - B)	+5.13
Robinson (Final Ambulation, F - H)	+3.25
Kolb (Final Ambulation, F - H)	+9.83
Bratcher, (Final Ambulation, E - F)	+3.27
Diaz, (Final Ambulation, E - F)	+1.43
McNeil (No Final Ambulation)	X
Wilson (Final Ambulation, G - H)	+7.62
Gieck (Final Ambulation, G - H)	+7.07
Graham (Final Ambulation, G - H)	+13.96

SUMMARY V

Changes in Bone Density of a Section of the Distal End of the Ulna, Resulting from Exercise and a Dietary Supplement.

A. Group following an Exercise Program during a Long Bed Rest. The three men who exercised during the 12-week Bed Rest during which exercise was taken while they were recumbent all gained in bone density during the Period, as was the case with the distal radius. The changes in bone density were: +2.00; +5.79; and +8.07 per cent, respectively.

B. Same Subjects as in Group A, who did not engage in Exercise. Two of the men made negative changes in bone density in a section of the distal ulna when the exercise was changed to no exercise, -1.82 and -6.61, respectively. One man gained in bone density in this anatomic site during this no-exercise period (+5.61 per cent).

C. Group receiving a Phosphate Supplement during Bed Rest. As in other cases, in which various bones were evaluated, five men took part in a 12-week Bed Rest during which a phosphate supplement was provided.

One man received the phosphate supplement during the shorter Bed Rest. The bone evaluated for skeletal density changes in Summary V was a section in the distal ulna.

In the case of the five men on the longer Bed Rest, three experienced reductions in bone density ranging from -3.17 to -10.33 per cent. Two increased in this factor by minor amounts, +2.26 and +3.64 percentages.

D. Same Men as in Group C, who received no Phosphate Supplement. The same participants who were in the previous group, but who received no phosphate supplementations, universally experienced reductions in bone density in amounts ranging from -1.49 to -6.32 per cent.

E. Changes in a Section of the Distal Ulna during Ambulation. Three men who had a brief initial period of ambulation before their first Bed Rest Period began increased in bone density of the distal ulna by values of +1.09, +4.50, and +10.94 per cent.

The seven subjects who had a final ambulation period which was evaluated radiographically increased to different amounts ranging from +3.18 to +9.03 per cent.

S U M M A R Y V

EFFECT OF EXERCISE AND PHOSPHATE DURING BED REST ON BONE DENSITY OF DISTAL ULNA

	Change in Bone Density (Per Cent)
A. Exercise	
Bratcher (1st 12-week Bed Rest, A - C)	+5.79
Diaz (1st 12-week Bed Rest, A - C)	+8.07
McNeil (1st 12-week Bed Rest, A - C)	+2.00
B. No Exercise	
Bratcher (2nd 12-week Bed Rest, C - E)	-6.61
Diaz (2nd 12-week Bed Rest, C - E)	+5.61
McNeil (2nd 12-week Bed Rest, C - E)	-1.82
C. Phosphate Supplement	
Robinson (2nd 12-week Bed Rest, C - E)	+3.64
Kolb (2nd 12-week Bed Rest, C - E)	-6.74
Wilson (1st 12-week Bed Rest, B - E)	-3.17
Gieck (1st 12-week Bed Rest, B - E)	+1.70
Graham (1st 12-week Bed Rest, B - E)	-10.33
McNeil (Only 6-week Bed Rest with Phosphate, E - F)	+2.26

SUMMARY V, CONTINUED

EFFECT OF EXERCISE AND PHOSPHATE DURING BED REST ON BONE DENSITY OF DISTAL ULNA

D. No Phosphate Supplement

	Change in Bone Density (Per Cent)
Robinson (1st 12-week Bed Rest, A - C)	-1.49
Kolb (1st 12-week Bed Rest, A - C)	-4.34
Wilson (2nd 12-week Bed Rest, E - G)	-6.32
Gieck (2nd 12-week Bed Rest, E - G)	-4.15
Graham (2nd 12-week Bed Rest, E - G)	-2.29
McNeil (Same as B above)	-1.82

E. Ambulation

Wilson (Initial Ambulation, A - B)	+4.50
Gieck (Initial Ambulation, A - B)	+10.94
Graham (Initial Ambulation, A - B)	+1.09
Robinson (Final Ambulation, F - H)	+5.54
Kolb (Final Ambulation, F - H)	+5.08
Bratcher (Final Ambulation, E - F)	+3.18
Diaz (Final Ambulation, E - F)	+7.22
McNeil (No Final Ambulation)	X
Wilson (Final Ambulation, G - H)	+9.03
Gieck (Final Ambulation, G - H)	+3.64
Graham (Final Ambulation, G - H)	+6.25

SUMMARY VI

Changes in Bone Density of a Section across the Capitate Resulting from Exercise and a Dietary Supplement

A. Group following an Exercise Program during a Long Bed Rest. The only three subjects who exercised during a long Bed Rest gained by relatively small amounts in the diagonal section across the capitate. The changes in the bone density of this bone for the three men were +1.12, +5.27, and 8.57 per cent, respectively.

B. Same Subjects as in Group A who did not engage in Exercise in this Bed Rest. Two of the men in this non-exercise group experienced negative bone density changes, -7.31 and -9.67 per cent, respectively. One man, who must have been flexing his wrist unduly, gained in bone density (+5.95 per cent).

C. Phosphate Supplement Provided. The phosphate supplement provided for this group during this Bed Rest was received by five men during a 12-week and by one in a shorter Bed Rest. Of the five men, two made positive (+2.92 and +7.34 per cent), while three made negative changes in bone density (-5.27, -6.56, and -13.04 per cent).

The one man in the shorter Bed Rest while receiving the phosphate supplement changed in bone density to the extent of -4.69 per cent.

D. Same Men as in Group C, who did not receive the Phosphate Supplement. The same five men as in Group C who did not receive the phosphate supplement made negative changes in bone density in the section of the capitate which was evaluated in all cases, with values ranging from -1.24 to -8.54 per cent. The one man who took part in the shorter Bed Rest made a gain in bone density of the capitate section of +5.95 per cent when no extra phosphate was provided.

E. Changes in Section of the Capitate during Ambulation. Summary VI shows that three subjects had brief initial ambulatory periods, with changes in bone density of a section of the capitate made by these men of -0.19, +8.36, and +15.56, respectively. Seven men had brief final ambulatory tests computed, while one left the study before taking a final x-ray on the day when he was leaving the investigation. Of the participants who had calculations made on their final ambulation periods for which radiographs were available for computations, all bone density changes were positive, with the seven men having changes in bone density ranging from +2.39 to +13.16 per cent.

SUMMARY VI

EFFECT OF EXERCISE AND PHOSPHATE DURING BED REST ON BONE DENSITY OF CAPITATE

A. Exercise

	Change in Bone Density (Per Cent)
Bratcher (1st 12-week Bed Rest, A - C)	+5.27
Diaz (1st 12-week Bed Rest, A - C)	+8.57
McNeil (1st 12-week Bed Rest, A - C)	+1.12

B. No Exercise

Bratcher (2nd 12-week Bed Rest, C - E)	-7.31
Diaz (2nd 12-week Bed Rest, C - E)	-9.67
McNeil (2nd 12-week Bed Rest, C - E)	+5.95

C. Phosphate Supplement

Robinson (2nd 12-week Bed Rest, C - E)	+2.92
Kolb (2nd 12-week Bed Rest, C - E)	-5.27
Wilson (1st 12-week Bed Rest, B - E)	+7.34
Gieck (1st 12-week Bed Rest, B - E).....	-6.56
Graham (1st 12-week Bed Rest, B - E)	-13.04
McNeil (Only 6-week Bed Rest with Phosphate, E - F)	-4.69

SUMMARY VI, CONTINUED

EFFECT OF EXERCISE AND PHOSPHATE DURING BED REST ON BONE DENSITY OF CAPITATE

D. No Phosphate Supplement

	Change in Bone Density (Per Cent)
Robinson (1st 12-week Bed Rest, A - C)	-1.24
Kolb (1st 12-week Bed Rest, A - C)	-6.61
Wilson (2nd 12-week Bed Rest, E - G)	-8.54
Gieck (2nd 12-week Bed Rest, E - G)	-1.83
Graham (2nd 12-week Bed Rest, E - G)	-2.41
McNeil (Same as B above)	+5.95

E. Ambulation

Wilson (Initial Ambulation, A - B)	-0.19
Gieck (Initial Ambulation, A - B)	+8.36
Graham (Initial Ambulation, A - B)	+15.56
Robinson (Final Ambulation, F - H)	+5.21
Kolb (Final Ambulation, F - H)	+7.32
Bratcher (Final Ambulation, E - F)	+2.39
Diaz (Final Ambulation, E - F)	+8.19
McNeil (No Final Ambulation)	X
Wilson (Final Ambulation, G - H)	+10.35
Gieck (Final Ambulation, G - H)	+6.20
Graham (Final Ambulation, G - H)	+13.16

OVERALL CHANGE IN BONE DENSITY OF SPECIFIED BONES DURING THE ENTIRE INVESTIGATION

It is of interest to find the overall change in bone density of majo bones which were included in the radiographs which were made during thi study. With x-rays made only of the foot (in lateral aspect) and of the hand in posterioanterior projection, as were taken of the astronauts, the the number of bones is limited. The sections included in the study are those which are outlined in the Appendix of this Report. Summary VII brings all the bones of each man which were evaluated radiologically together, and the 16 parts of Diagram III, which follow the Summary, show some details of three of the skeletal areas graphically.

Robinson. This subject spent 255 days from the time when his first until the time when his last radiographs were made. Summary VII shows that multiple sections of the os calcis, the distal ulna, and the capitate had lost bone density during the investigation.

Diagram III, 1A shows the progress of the overall multiple section of the os calcis during the various portions of the study. Throughout this entire period, the only time when the bone density of the os calcis reache its initial status was at the time when the last radiograph was taken at th close of the Bed Rest Period when the phosphate supplement had been fed

At the close of the study, the os calcis was 10.44 per cent below its initial status.

Diagram III - 1B shows the progress of the bone density levels of hand phalanges 4/2 and 5/2. Phalanx 4/2 rarely came above the level of the initial bone density, and fell below during the phosphate supplement period. Phalanx 5/2, on the other hand, was above the initial bone level much of the time, with the final level 25.97 per cent above its initial level.

Kolb. Kolb entered the study under consideration at the same time as that of Robinson, and remained for the same period of time. Diagram III - 2A shows that the bone density of the overall sections of the os calcis remained below the bone density of the initial level throughout the study. The final bone density of this bone was only 2.10 per cent below its initial level. From Diagram III - 2B, it is seen that phalanx 4/2 fell below the initial bone density level of this bone for Kolb throughout the first two 12-week Bed Rest Periods, then fell below this level for a short time and then rose until it was virtually level with the initial bone density of this skeletal site.

Hand phalanx 5/2 was higher than its initial bone density through the first two bed rest periods. Then it fell through the third period, and then rose to its initial status at the close of the study.

Summary VII shows that distinctly negative bone density levels ar found in Kolb for the sections across the distal radius, the distal ulna, and the capitate at the close of the investigation.

Bratcher. Bratcher remained in the study for 188 days. He chang in bone density level of the multiple sections of the os calcis only slight throughout the study. This was only 3.20 per cent above the initial bone density level of this bone at the time of the last radiogram. See Diagram III - 3A.

Diagram III - 3B illustrates the fact that both the phalanges 4/2 and 5/2 rose during the first long Bed Rest Period (Bed Rest with Exercise fell during the second long Bed Rest (Bed Rest without Exercise), and were beginning to increase during a very short ambulatory period. Summary VII verifies the finding that the final bone density level of the os calcis is 3.20 per cent higher than the initial, and that hand phalanges 4/2 and 5/2 are slightly lower in bone density finally than initially.

The distal radius and the distal ulna were slightly higher at the close than at the beginning of the investigation.

Diaz. This man remained in the study for 188 days while radiographs were being made, for the same period of time as Bratcher. His bone density level of the os calcis remained relatively close to its initial level, except at the close of the second Bed Rest Period (Bed Rest with

no Exercise and no dietary supplement), when it lost markedly. At the time of the last x-ray, after a short ambulation period, it was close to its initial status (+1.04 per cent). See Diagram III, 4A and Summary VII.

In Summary VII, and Diagram III - 4B, it is seen that phalanges 4/2 and 5/2 performed in somewhat the same manner as Bratcher, responding to the exercise and no exercise as expected, and with slight increases during the short, final ambulation period. Summary VII shows that the distal radius lost slightly and the distal ulna gained markedly in comparison with the initial status of these bones. The capitate also made some positive change (+6.10 per cent). This subject was in the study 188 days from the first until the final x-rays.

McNeil. McNeil hovered slightly above the initial bone density level for the multiple sections of the os calcis throughout his participation in the study undergoing consideration at this time. He experienced no final ambulatory period because of leaving the study before it was anticipated, so that he did not receive his last radiograph. At the time of his last x-ray test, in the midst of his short Bed Rest during which he was receiving a phosphate supplement, his os calcis bone density status was 4.85 per cent above his first test. See Summary VII and Diagram III - 5A.

Diagram III - 5B shows a somewhat different response to the exercise experience in phalanx 4/2 and phalanx 5/2 than was found with the

other men, probably because he had lost his left arm and was given a different form of exercise than the others on the same program.

At the close of the study, this man had gained slightly in the section at the distal end of the radius (+8.84 per cent), at the distal ulna (+2.40 per cent), and in the capitate (+2.10 per cent). The values in the wrist and arm relate to his right arm, because of the loss of the left arm which is the one usually radiographed.

Wilson. Wilson had been a participant in the study from the first to the last radiograph for 224 days. In the multiple os calcis sections, his bone density had increased during the long Bed Rest when a phosphate dietary supplement was provided. It decreased during the next Bed Rest when no phosphate was fed, and ended at virtually the same bone density as initially. See Diagram III - 6A and Summary VII.

Diagram III - 6B shows that, for this subject, phalanx 4/2 rose over its initial bone density throughout the study, and closed 11.76 per cent higher than initially. On the other hand, phalanx 5/2 was slightly below the initial bone density for this level throughout most of the period with a value of -4.23 per cent at the time of the final radiograph. See Summary VII and Diagram III - 6B.

From the cited Summary, the bones of the wrist and distal arm increased in bone density with the final values higher than the initial.

Gieck. This subject was in the study 246 days between first and last radiographs. In the total of the multiple sections of the os calcis, this subject was slightly higher in bone density throughout the two Bed Rest Periods with and without phosphate supplementation. He increased in bone density of the os calcis during his short final ambulation period, with his last radiograph 13.80 per cent higher in bone density than his first radiograph of the study. See Diagram III - 7A.

In Diagram III - 7B, phalanges 4/2 and 5/2 increased to points higher than their initial bone density status early in the investigation and remained above their initial levels throughout. Phalanx 4/2 made a last increase during the final ambulation period, with a final level 27.48 per cent above the initial level. Phalanx 5/2 was 8.84 per cent above the first bone density level. The distal radius and ulna sections as well as the section of the capitate in the subject were all higher in the final than in the first radiograph. See Summary VII.

Graham. This subject was in the investigation 246 days between the initial and final x-rays. He gained 17.26 per cent in bone density between the first and last radiograph of the os calcis. See Diagram III - 8A and Summary VII. The Diagram shows that Graham increased in the bone density of the os calcis beginning with his first ambulation period, and through the long Bed Rest when a phosphate supplement was fed. Then the bone density fell during the Bed Rest Period, when the phosphate

supplementation was not provided, and increased again during the re-ambulation period.

Diagram III - 8B shows the bone density changes in the phalanx 4/2 to increase markedly after the first x-ray, and to remain distinctly higher than the initial level throughout the investigation. Phalanx 5/2, on the other hand, hovered close to the initial level until the Bed Rest Period during which the phosphate supplement was not fed. Then this wa reduced, with a slight rise during the final ambulation. At the time when the final radiograph was taken, bone density of phalanx 5/2 was 2.92 pe cent below its initial level.

At the time of the final x-ray, Grahăm's distal radius had a value which was 5.91 per cent above, the distal ulna was 5.90 per cent below, and the diagonal section across the capitate was 10.97 per cent higher than the initial value of the same bone sections. See Summary VII.

SUMMARY VII

BONE DENSITY CHANGE DURING THE INVESTIGATION OF SPECIFIED BONES FOR RESPECTIVE SUBJECTS

ROBINSON

Skeletal Location of Bone which was Evaluated	Bone Density Change from Initial to Final Radiograph (per cent)
Multiple Sections of Os Calcis	-10.44
Hand Phalanx 4/2	+1.77
Hand Phalanx 5/2	+25.97
Distal Radius	+0.78
Distal Ulna	-9.50
Capitate	-13.17

KOLB

Skeletal Location of Bone which was Evaluated	Bone Density Change from Initial to Final Radiograph (per cent)
Multiple Sections of Os Calcis	-2.10
Hand Phalanx 4/2	-0.01
Hand Phalanx 5/2	+0.34
Distal Radius	-14.27
Distal Ulna	-13.95
Capitate	-11.31

SUMMARY VII, CONTINUED

BONE DENSITY CHANGE DURING THE INVESTIGATION OF SPECIFIED BONES FOR RESPECTIVE SUBJECTS

BRATCHER

Skeletal Location of Bone which was Evaluated	Bone Density Change from Initial to Final Radiograph (per cent)
Multiple Sections of Os Calcis	+3.20
Hand Phalanx 4/2	-2.39
Hand Phalanx 5/2	-0.14
Distal Radius	+2.86
Distal Ulna	+1.94
Capitate	-0.09

DIAZ

Skeletal Location of Bone which was Evaluated	Bone Density Change from Initial to Final Radiograph (per cent)
Multiple Sections of Os Calcis	+1.04
Hand Phalanx 4/2	+9.11
Hand Phalanx 5/2	-1.52
Distal Radius	-1.44
Distal Ulna	+22.37
Capitate	+6.10

SUMMARY VII, CONTINUED

BONE DENSITY CHANGE DURING THE INVESTIGATION OF SPECIFIED BONES FOR RESPECTIVE SUBJECTS

McNEIL

Skeletal Location of Bone which was Evaluated	Bone Density Change from Initial to Final Radiograph (per cent)
Multiple Sections of Os Calcis	+4.85
Hand Phalanx 4/2	-4.88
Hand Phalanx 5/2	-5.84
Distal Radius	+8.84
Distal Ulna	+2.40
Capitate	+2.10

WILSON

Skeletal Location of Bone which was Evaluated	Bone Density Change from Initial to Final Radiograph (per cent)
Multiple Sections of Os Calcis	+0.10
Hand Phalanx 4/2	+11.76
Hand Phalanx 5/2	-4.23
Distal Radius	+8.66
Distal Ulna	+3.35
Capitate	+8.13

SUMMARY VII, CONTINUED

BONE DENSITY CHANGE DURING THE INVESTIGATION OF SPECIFIED BONES FOR RESPECTIVE SUBJECTS

GIECK

Skeletal Location of Bone which was Evaluated	Bone Density Change from Initial to Final Radiograph (per cent)
Multiple Sections of Os Calcis	+13.80
Hand Phalanx 4/2	+27.48
Hand Phalanx 5/2	+8.84
Distal Radius	+12.62
Distal Ulna	+14.44
Capitate	+5.56

GRAHAM

Skeletal Location of Bone which was Evaluated	Bone Density Change from Initial to Final Radiograph (per cent)
Multiple Sections of Os Calcis	+17.26
Hand Phalanx 4/2	+30.41
Hand Phalanx 5/2	-2.92
Distal Radius	+5.91
Distal Ulna	-5.90
Capitate	+10.97

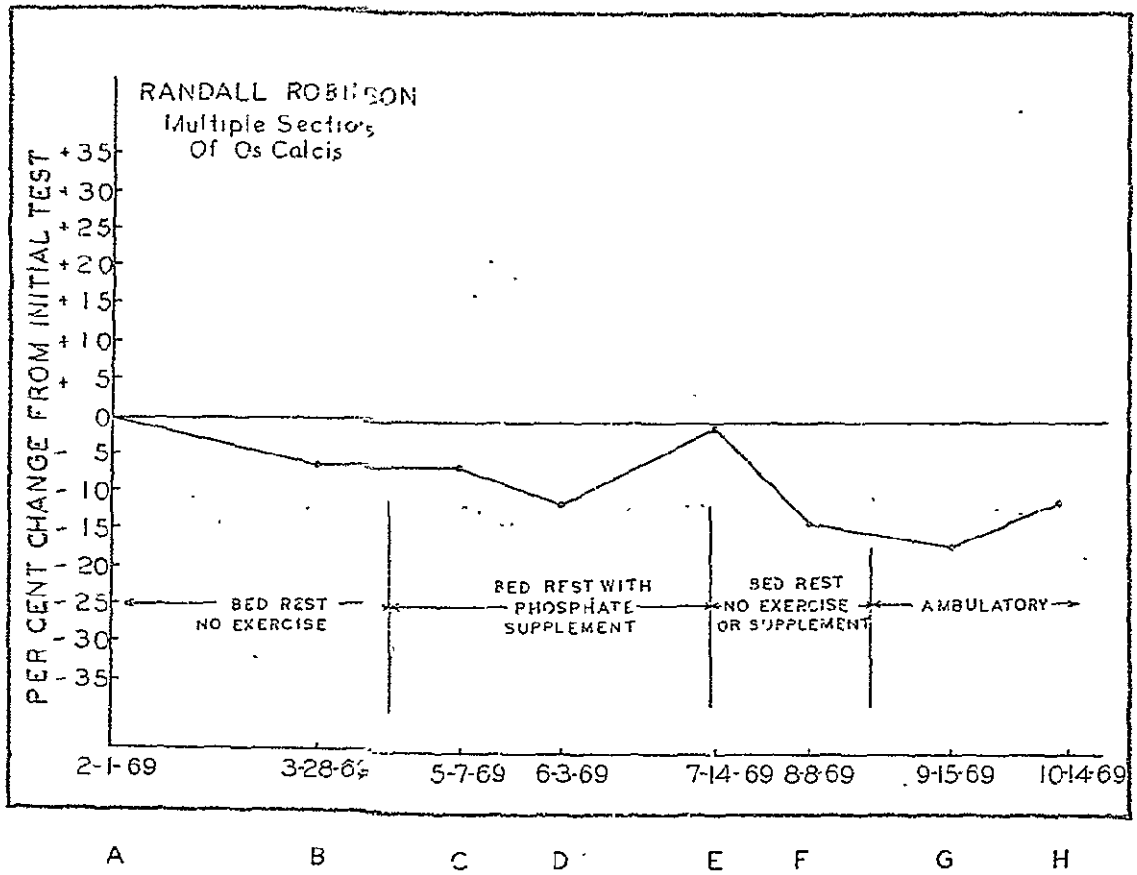

Diagram III - 1A

Change of Each Radiograph of the Total Multiple Sections of the Os Calcis of Robinson Computed in Each Case from the Initial Radiograph.

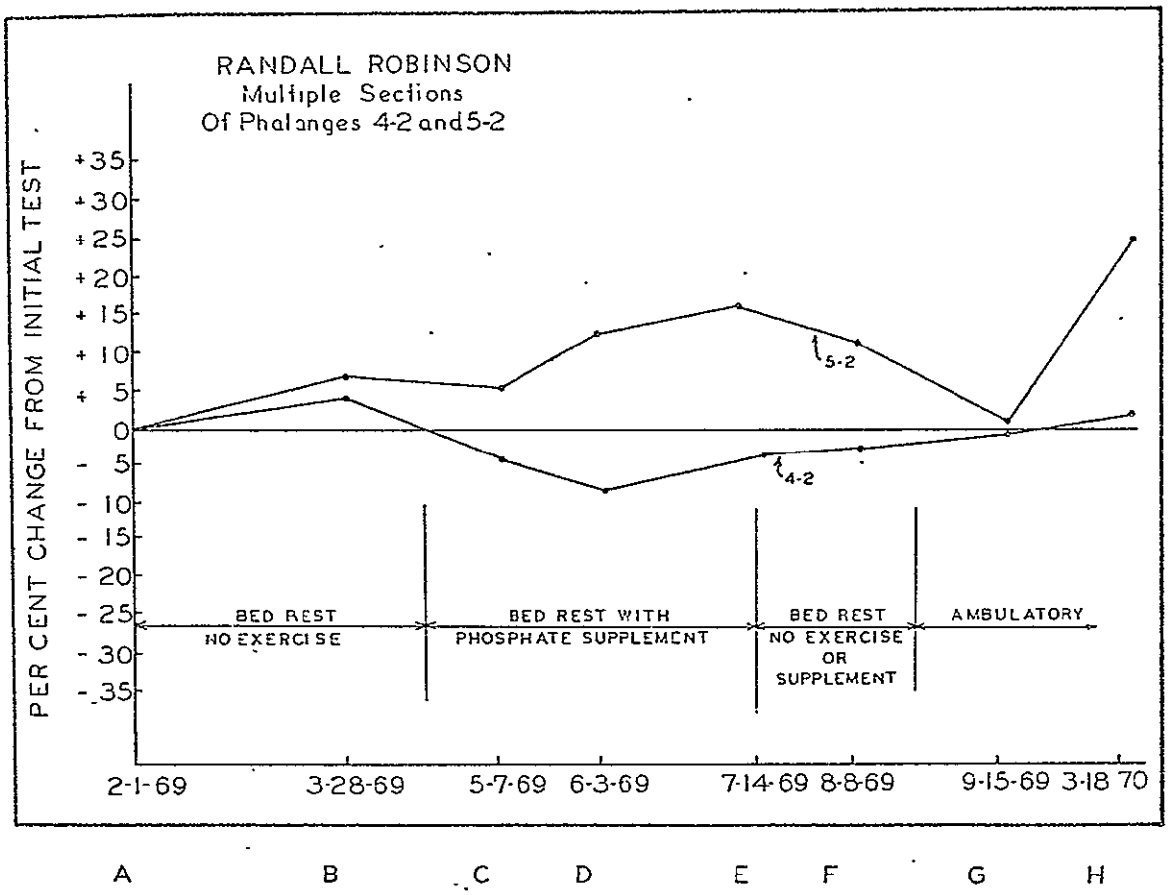

Diagram III - 1B

Change of Each Radiograph for Phalanges 4-2 and 5-2,

Computed from the Initial Value for Robinson.

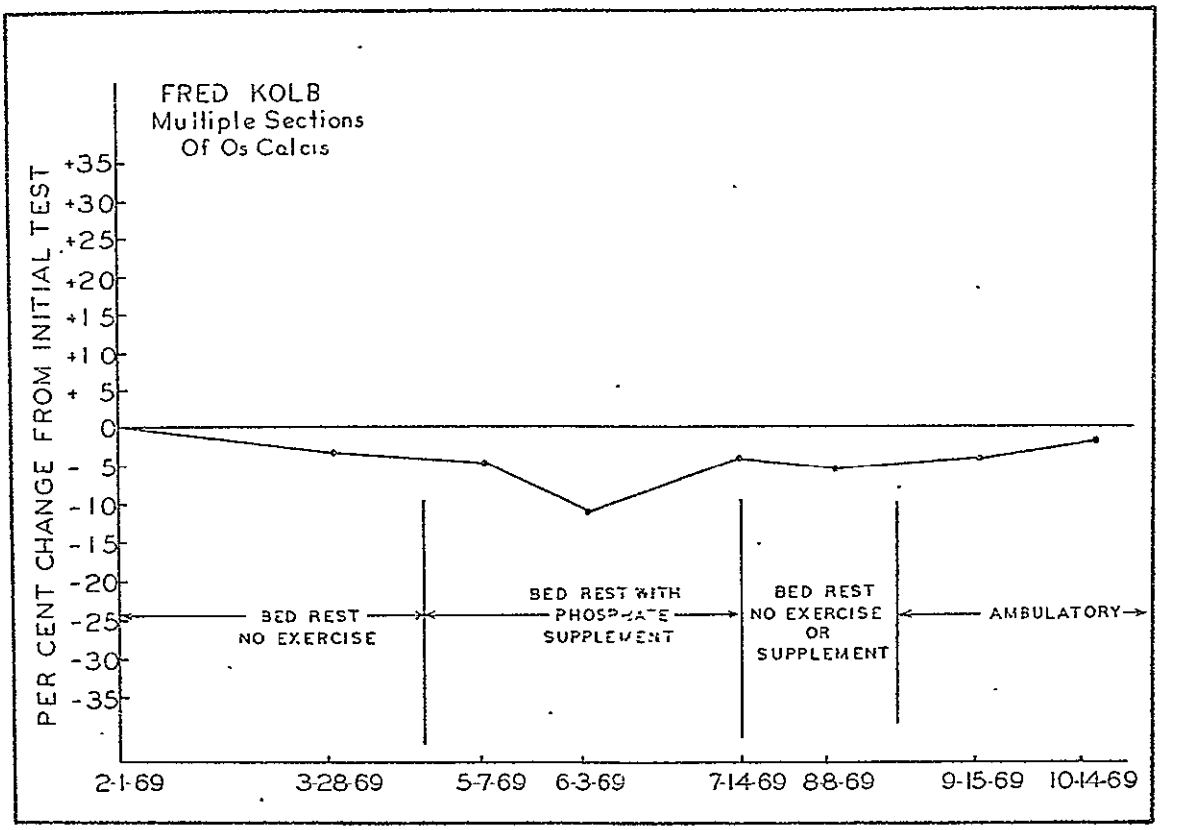

Diagram III - 2A

Change of Each Radiograph of the Total Multiple Sections of the Os Calcis of Kolb Computed in Each Case from the Initial Radiograph.

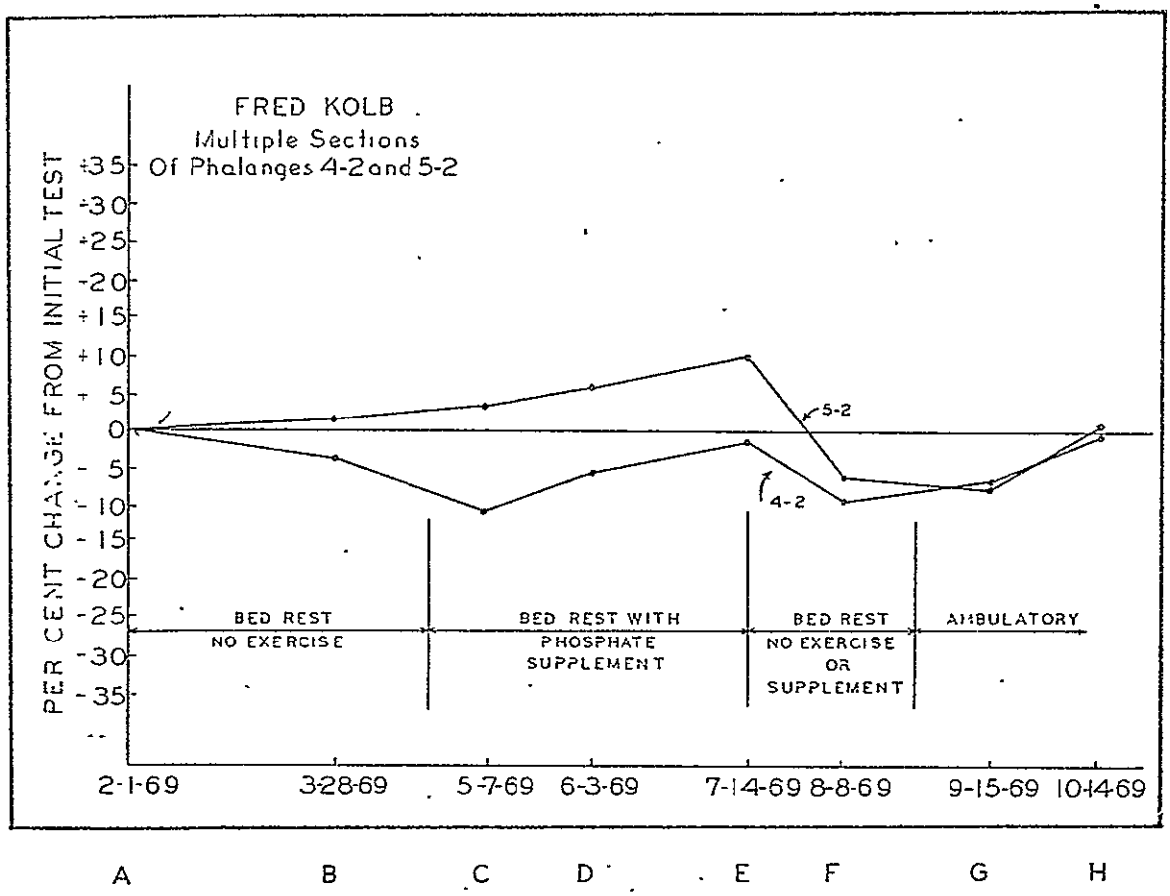

Diagram III - 2B

Change of Each Radiograph for Phalanges 4-2 and 5-2,

Computed from the Initial Value for Kolb.

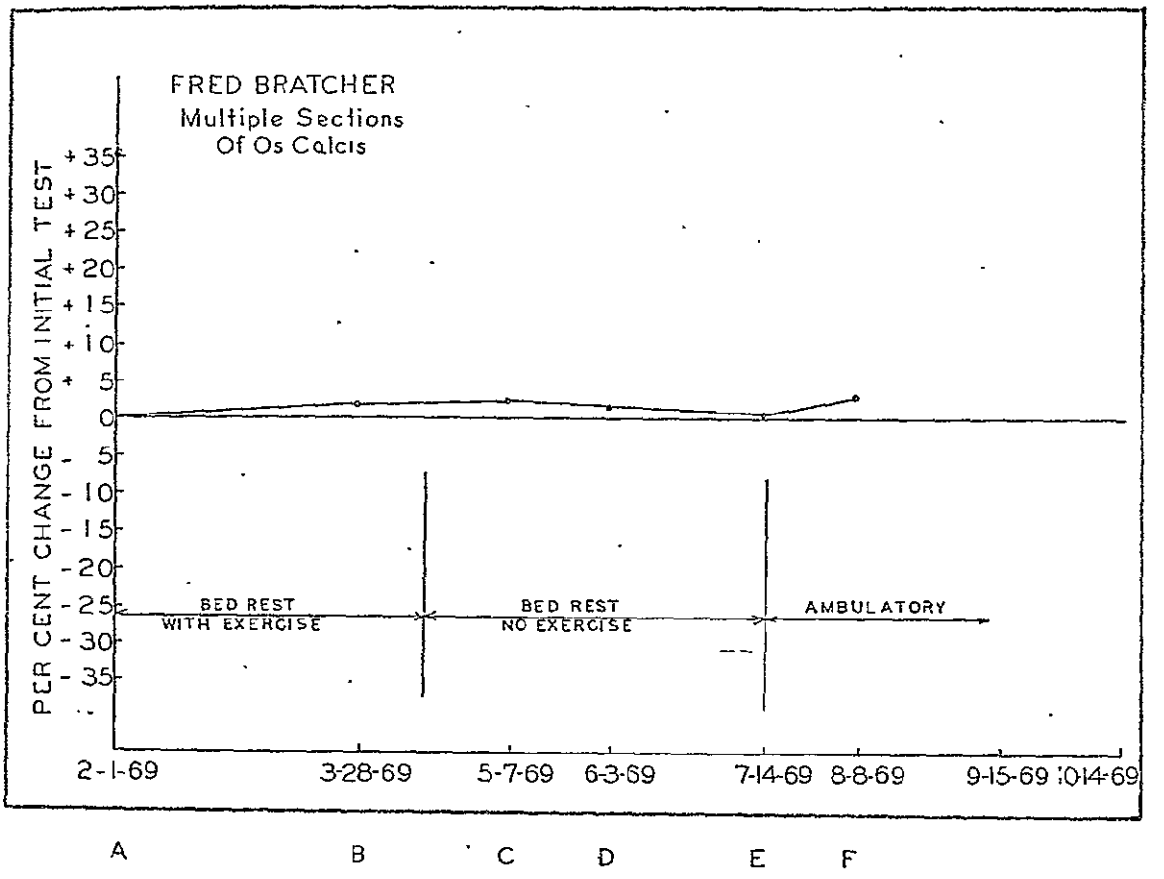

Diagram III - 3A

Change in Each Radiograph of the Total Multiple Sections of the Os Calcis of Bratcher Computed in Each Case from the Initial Radiograph.

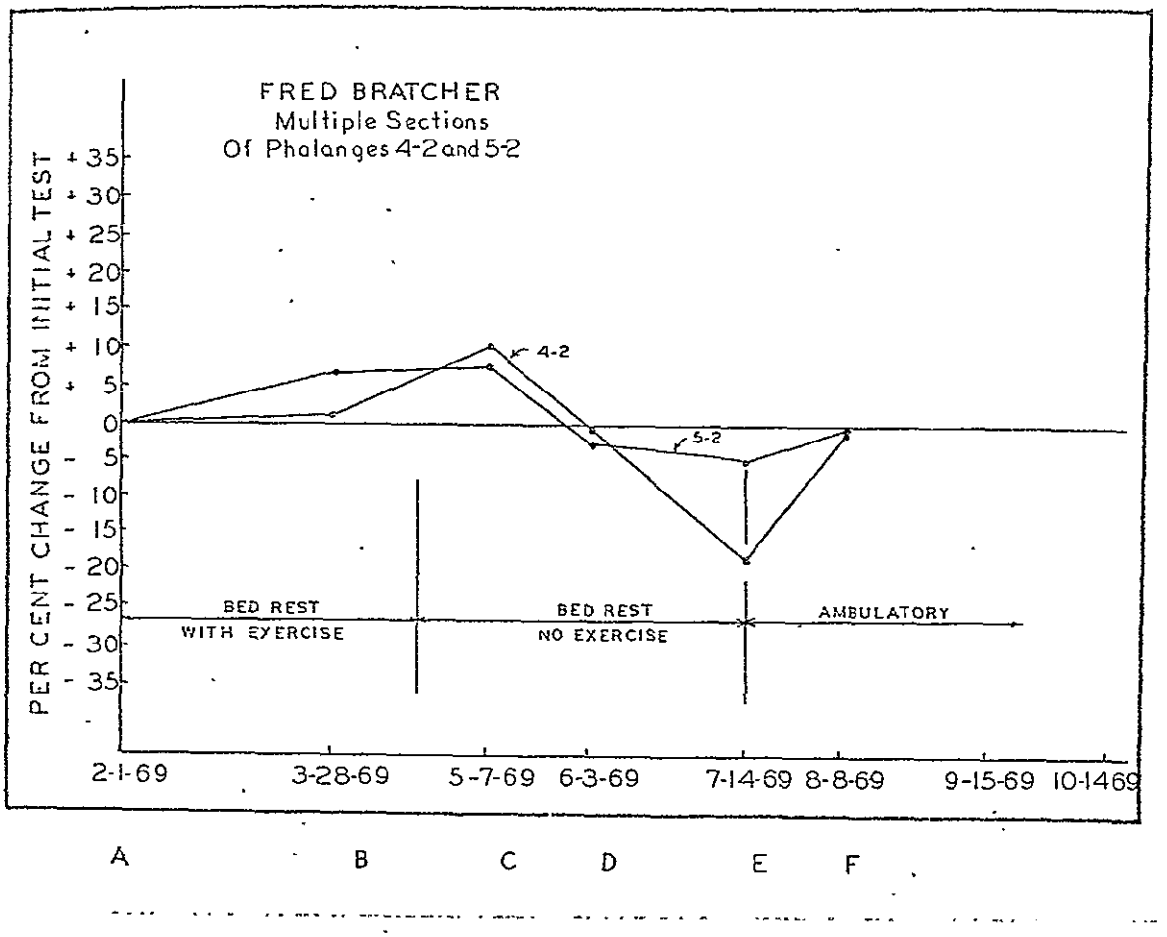

Diagram III - 3B

Change of Each Radiograph for Phalanges 4-2 and 5-2,

Computed from the Initial Value for Bratcher.

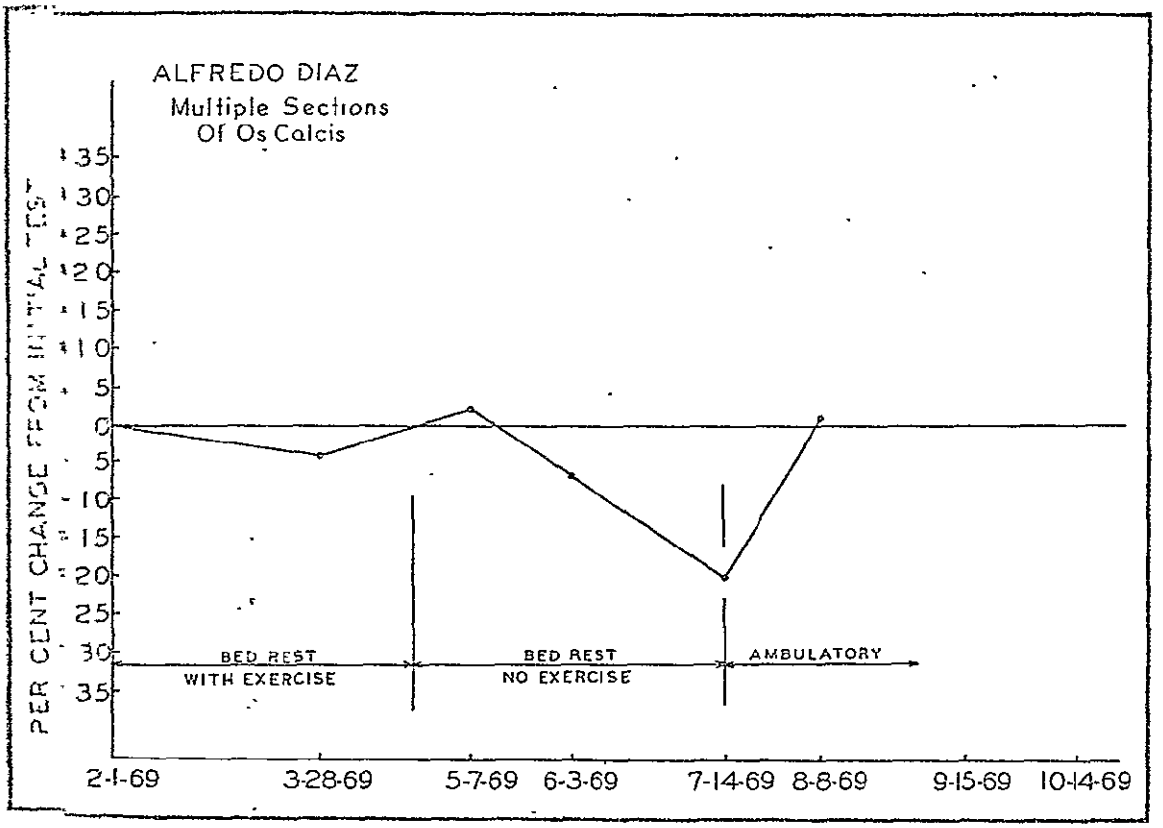

Diagram III - 4A

Change of Each Radiograph of the Total Multiple Sections of the Os Calcis of Diaz Computed in Each Case from the Initial Radiograph.

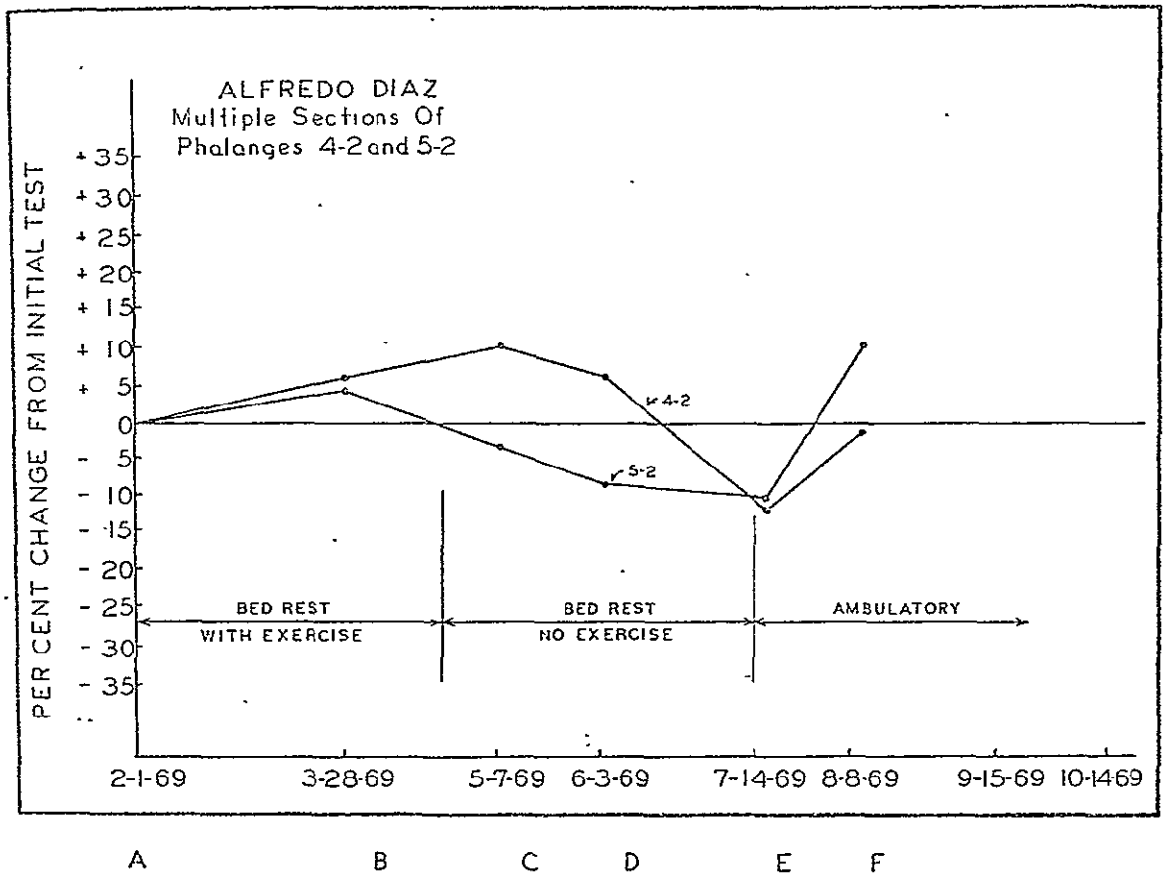

Diagram III - 4B

Change of Each Radiograph for Phalanges 4-2 and 5-2,

Computed from the Initial Value for Diaz.

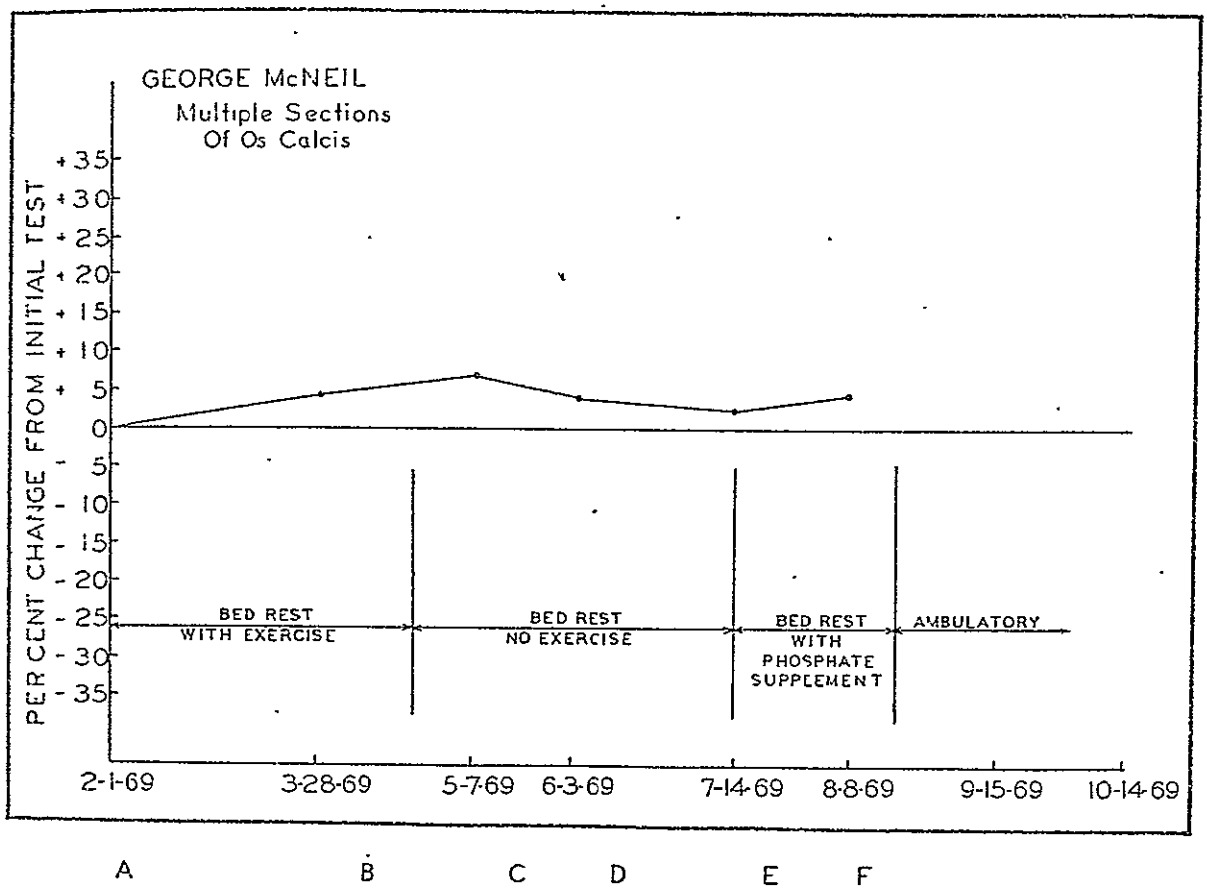

Diagram III - 5A

Change in Each Radiograph of the Total Multiple Sections of the Os Calcis of McNeil Computed in Each Case from the Initial Radiograph.

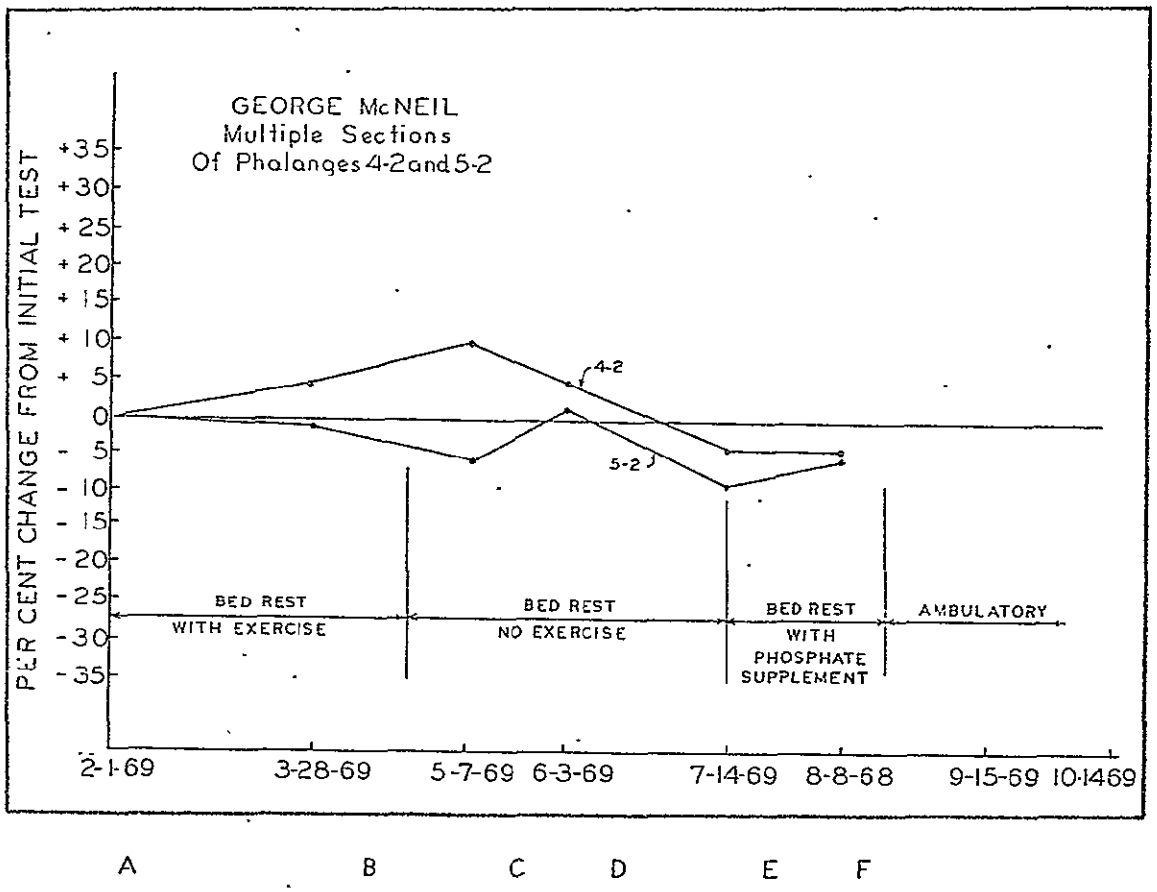

Diagram III - 5B

Change of Each Radiograph for Phalanges 4-2 and 5-2,

Computed from the Initial Value for McNeil.

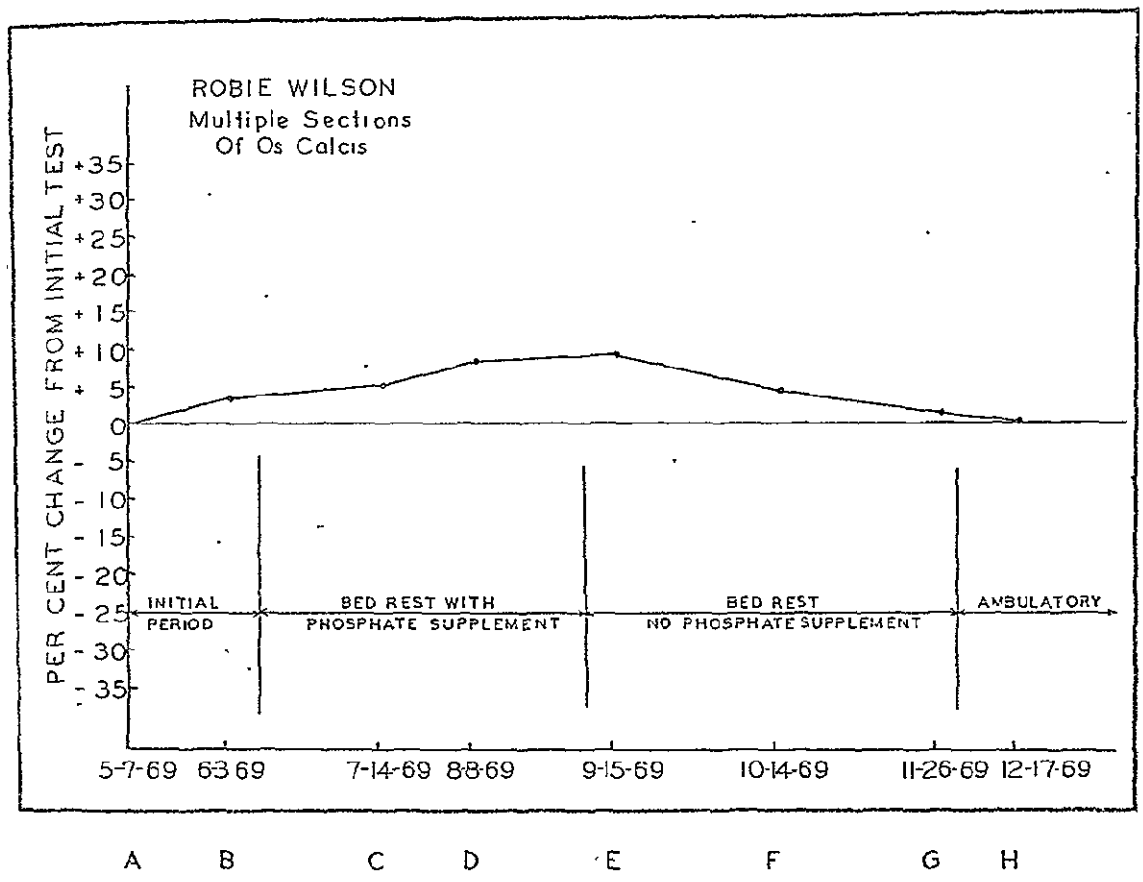

Diagram III - 6A

Change of Each Radiograph of the Total Multiple Sections of the Os Calcis of Wilson Computed in Each Case from the Initial Radiograph.

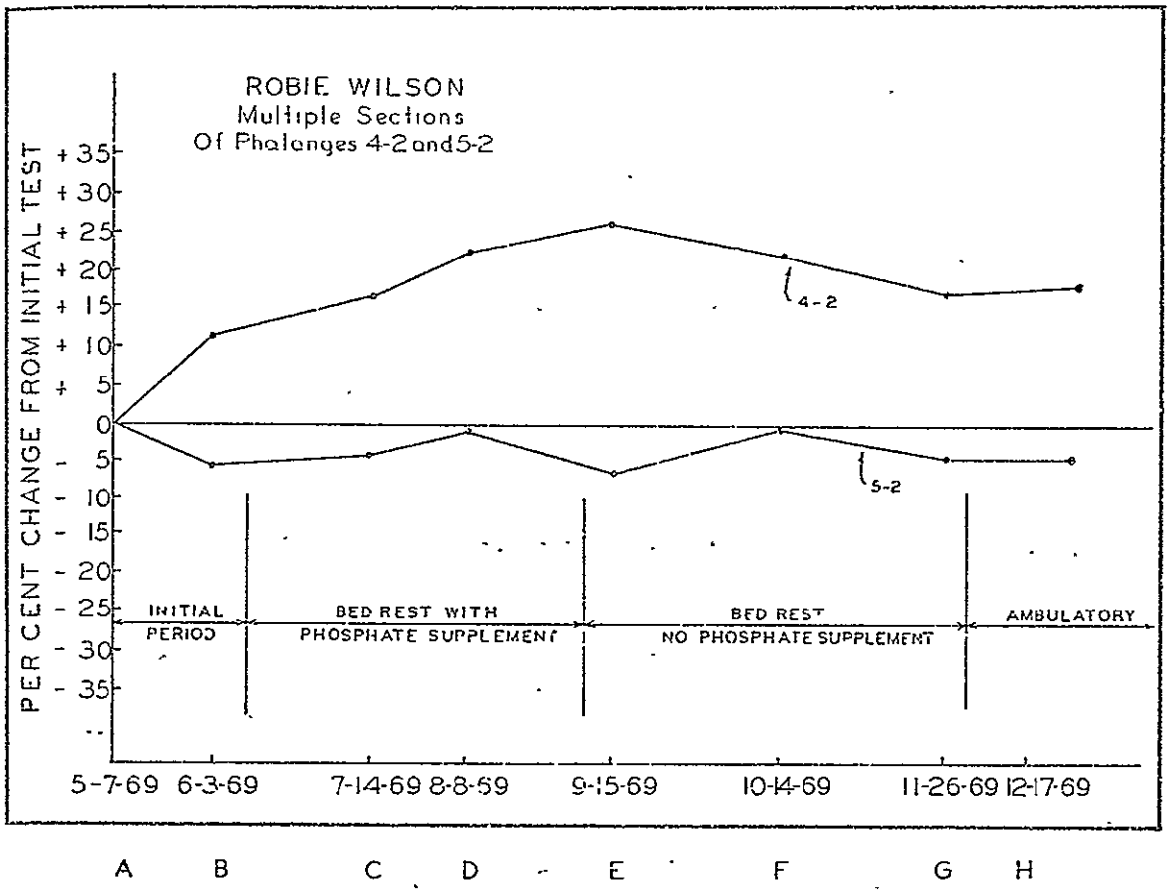

Diagram III - 6B

Change of Each Radiograph for Phalanges 4-2 and 5-2,

Computed from the Initial Value for Wilson.

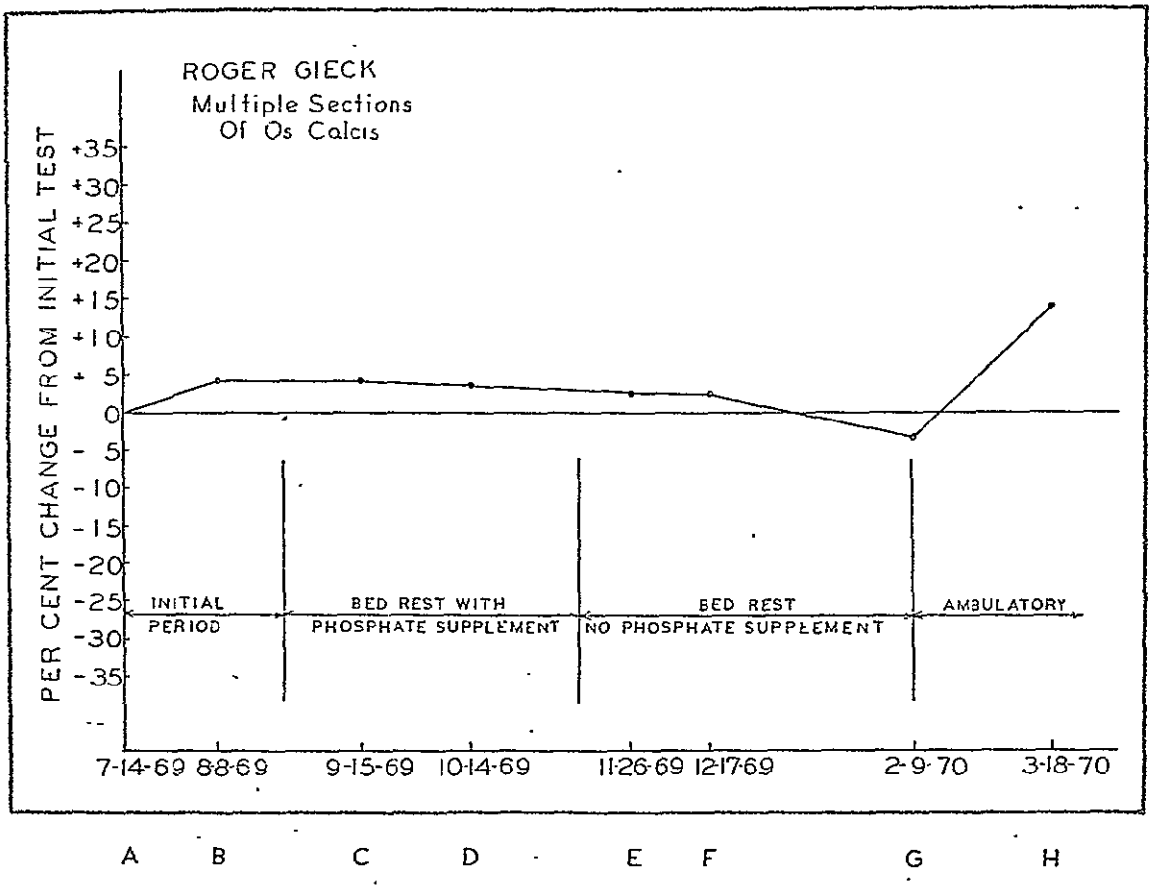

Diagram III - 7A

Change of Each Radiograph of the Total Multiple Sections of the Os Calcis of Gieck Computed in Each Case from the Initial Radiograph.

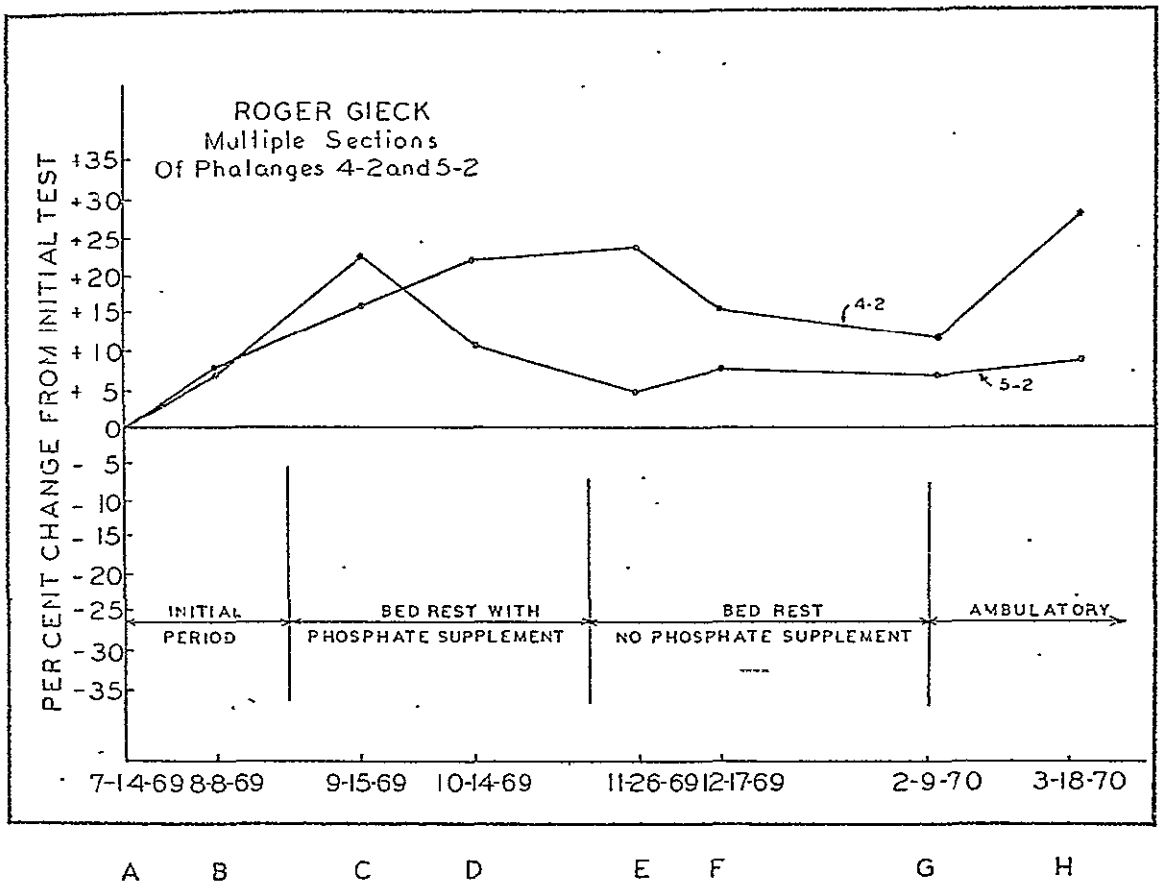

Diagram III - 7B

Change of Each Radiograph for Phalanges 4-2 and 5-2,

Computed from the Initial Value for Gieck.

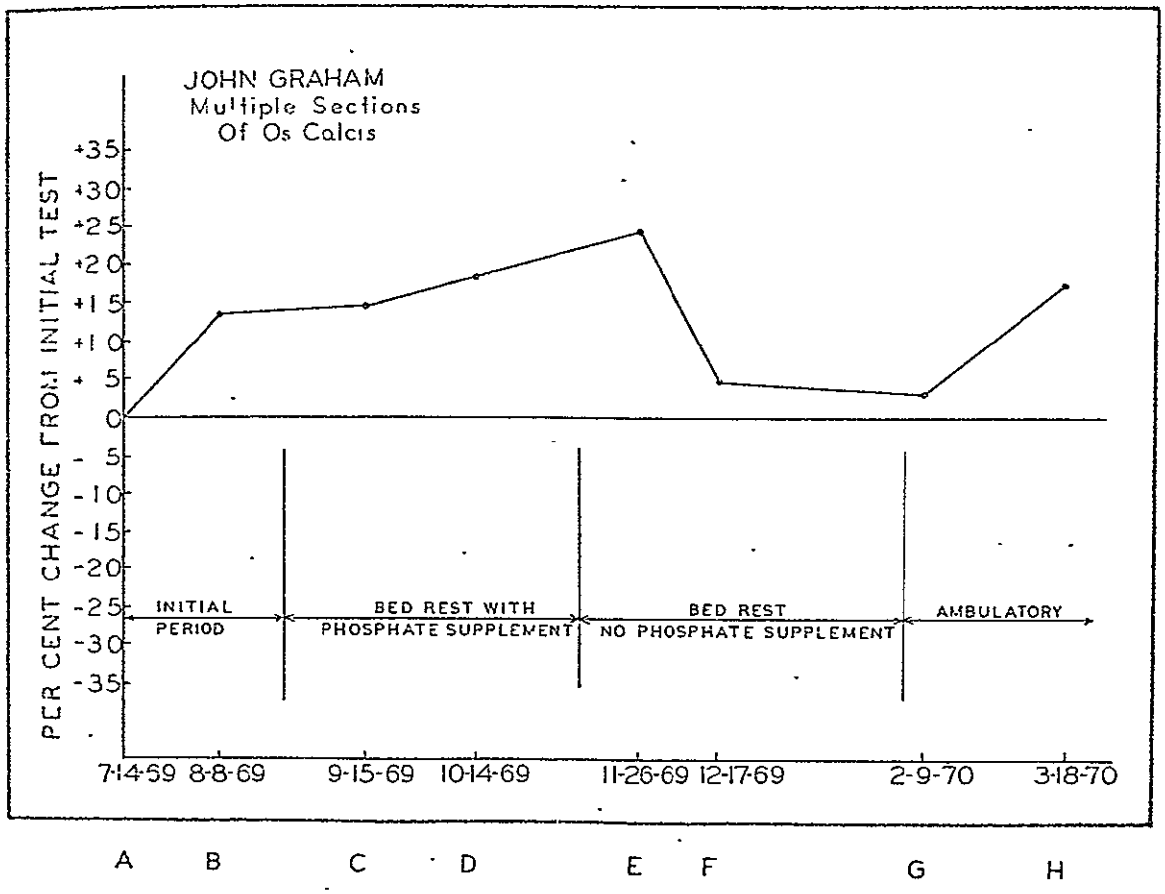

Diagram III - 8A

Change of Each Radiograph of the Total Multiple Sections of the Os Calcis of Graham Computed in Each Case from the Initial Radiograph.

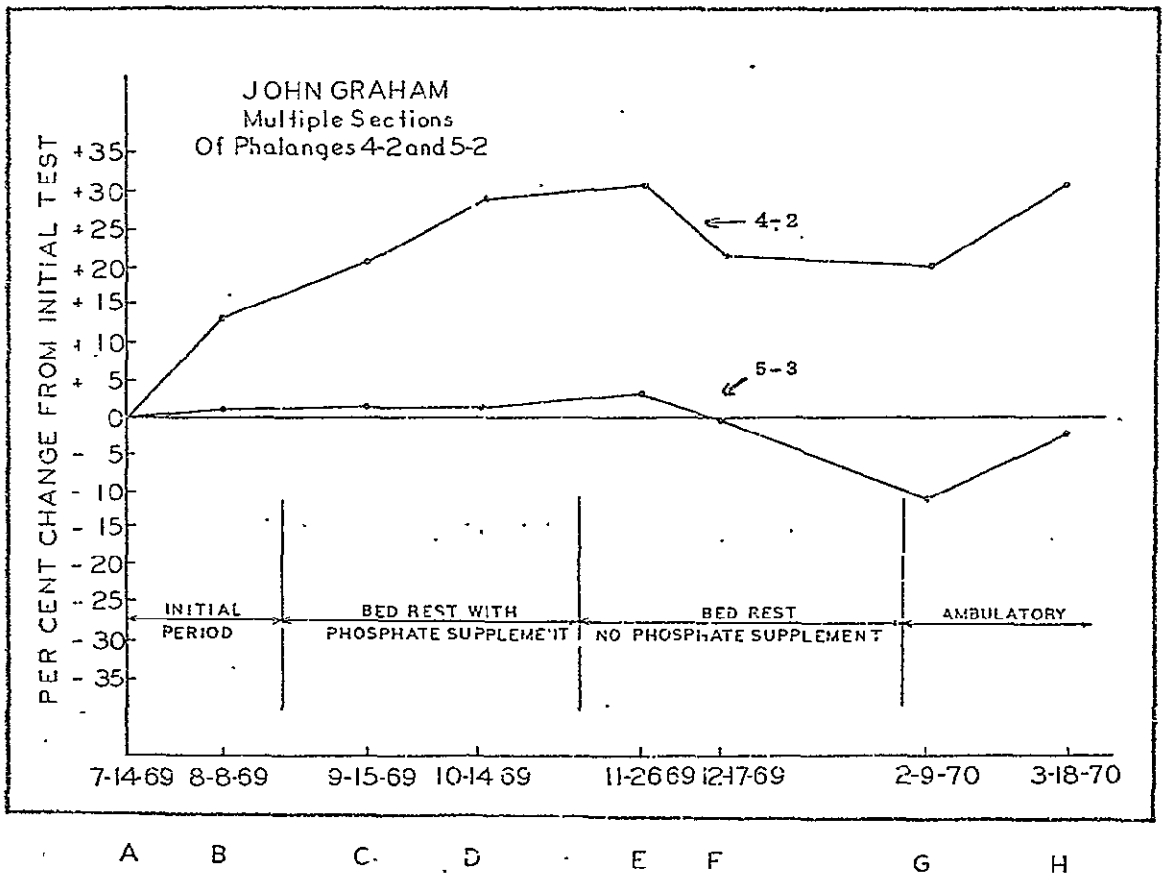

Diagram III - 8B

Change of Each Radiograph for Phalanges 4-2 and 5-2,

Computed from the Initial Value for Graham.

TWU BONE DENSITY METHOD

To describe the Texas Woman's University bone density methodology, the history of the method has been described in the Journal of the Association for the Advancement of Medical Instrumentation, in Volume 3, page 110, May, 1969 on Automated Techniques in Bone Densitometry. A reprint of this article is available from this office on request.

From the beginning of the development of workable bone densitometric equipment, a wedge which served as a calibration standard was placed on the same film as that on which a bone was x-rayed. After a trial of various materials, an aluminum alloy wedge was developed with a continuous slope, which had x-ray transmission characteristics similar to that of bone.

The purpose of the calibration wedge has not been to match the density of any portion thereof with a section of bone, as was done with many of the early step wedges, but to find the deviation of the initial densitometer wedge scan from the configuration of a trace which would correspond to its actual slope, thus serving to give a basis for correcting a bor trace on the same film. It never was assumed that the raw bone trace could be used directly without correction because of unavoidable differences, although usually not large, in x-ray film, in exposure energy, and in developmental techniques.

The units which come off of the bone densitometric assembly are in the form of Integrator Counts. The Integrator Counts can be converted into units of calibration wedge mass equivalency.

After the integrator count has been obtained for the calibrated bone scan, this is converted into equivalent x-ray mass of calcium hydroxyapatite 3 $Ca_3 (PO_4)_2 \cdot Ca (OH)_2$ from these calculations:

$$\text{Equivalent wedge mass} = \frac{S.L.V.H.C}{K} \quad (cm.^3)D$$

Where S = Slope of wedge;

L = Baseline length of wedge traced;

V = Velocity of scan (cm./min.);

H = Vertical dimension of the scanning slit (cm.);

K = Counts obtained for one minute of full scale integration (counts/min.);

C = Integrator counts; and

D = the density of the aluminum alloy calibration wedge.

The equivalent x-ray mass of calcium hydroxyapatite, with the formula shown above, which represents the calcium complex used for calibration of the wedges of this laboratory, can be obtained as follows for the sections of bone traced on the same film.

$$\text{Equivalent x-ray Mass of Apatite} = \frac{\text{S.L.V.C.H.}}{\text{K}} \times 1.075$$

Where 1.075 = Ratio of wedge density to calcium hydroxyapatite density

The term 5,000 is based upon the fact that a full scale integration carried out for one minute results in an integrator count of 5,000 (K in the above formula).

In arriving at the determination of the ratio of wedge density to calcium hydroxyapatite density, our group made an intimate mixture of $Ca_3(PO_4)_2$ and $Ca(OH)_2$ in the exact proportion of these components in calcium hydroxyapatite, placed this in a thin-walled plastic container which was calibrated separately, and x-rayed this and the aluminum alloy wedge together. The ratio of the two was calculated from their respective masses and from the results of multiple scans traced across thei radiographic images.

The microdensitometric assembly has been evaluated on two bases, as follows: (a) by finding the capacity of the equipment to integrate bone areas accurately from roentgenograms exposed through a series of intensity values; and (b) by ascertaining the interrelationship of the mass of cadaver bones by analytical and by radiographic procedures.

Some automation was built into a bone densitometric assembly using funds provided by Mr. and Mrs. H. J. Lutcher Stark of Orange, Texa: The equipment consisted of a special analogue computer which possessed an electromechanical servomechanism and an integrating unit. The major units of this instrumentation, which was used in evaluating the radiographs in the TWU Laboratories for several years before it was supported by the addition of a digital computer are shown in Figure 1. The equipment consists of five major subassemblies, all designed to operate together as a completely integrated system. The basic units of the overall assembly were the following:

1) A modified Knorr-Albers scanning unit (unit at right of the figure);

2) A Speedomax Model G transmitting recorder (unit in center of the figure);

3) A series of 20 potentiometers in the same panel as 2);

4) A Speedomax Model G recording potentiometer (unit at left of the figure), and

5) An Integrator (unit in the panel under Unit d).

To obtain a satisfactory calibration for a trace of a bone section from an x-ray film, the fundamental step in the analogue system is provided in the use of the calibration wedge on the same film as the bone image, as noted. The initial record obtained on the first recorder from scanning the wedge by means of the densitometer without correction provides the basis for calibrating the wedge curve for the film. The slope of this uncorrected

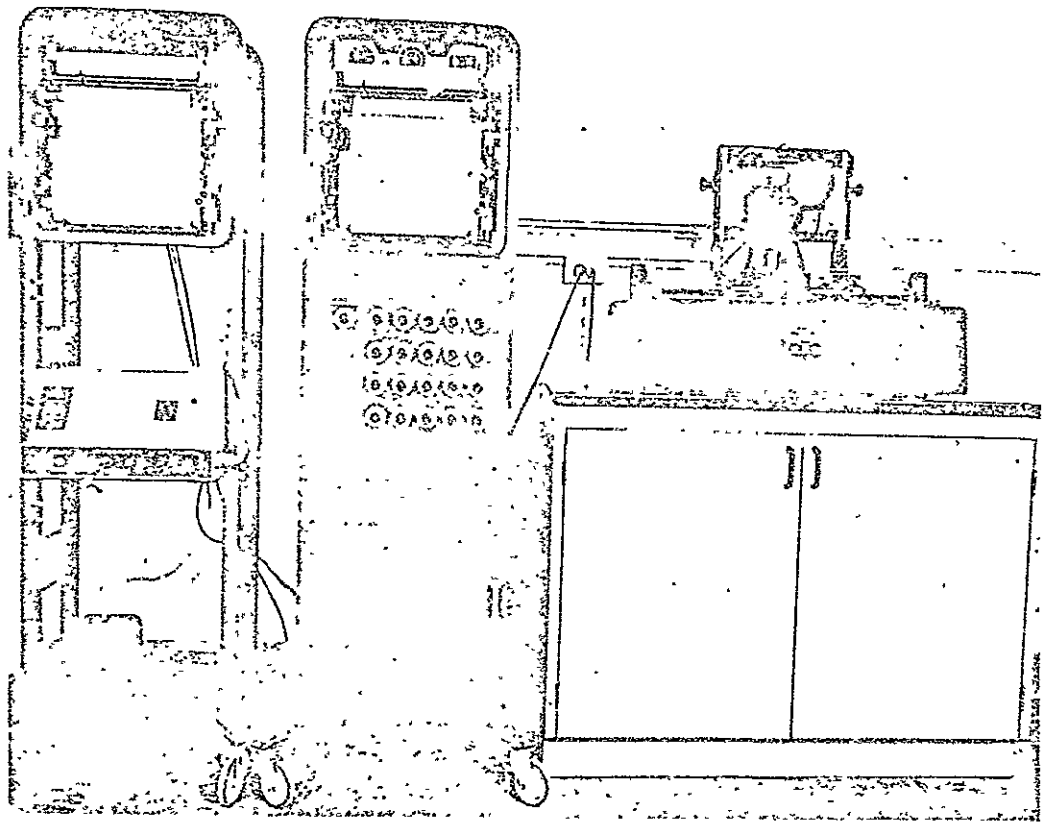

Figure 1. Densitometer Assembly VI developed at the Texas Woman's University. Right: densitometer; center (upper): transmitting recorder for tracing calibration wedge; center (lower): potentiometers for correcting calibration wedge trace; left: recording potentiometer with Instron integrator in lower part of panel.

curve is influenced by many factors inherent in the film itself, the film exposure, and the film processing technique.

The sequence of operations needed to achieve calibration of a density curve and to integrate the area under the curve of a bone on the same radiograph follows:

1) The wedge roentgenographic image first is scanned for the purpose of providing the density calibration curve of that film on the first recorder. The scanning unit consists of an optical system, a plate stage, a drive mechanism for the plate stage, and a d-c amplifier for the recorder. The optical system includes a special tungsten lamp with plane optically polished windows, powered from a highly stabilized power pack having a constancy of output with 0.1% for a-c line voltages between 100 and 125 v at frequencies between 55 and 65 cycles. The beam from this lamp is focused on a photocell after passing through the x-ray plate being scanned. The film is mounted on the plate stage that is supported by ball-bearing rollers on a carriage rod, all accurately machined to very close tolerance.

A scale, mounted on the scanning unit and calibrated to millimeters subdivided by a vernier, indicates plate travel, and enables the operator to scan a number of precisely equal segments of the film trace. This scale also permits the operator to retrace exactly the same length of film on repeated scans, and serves as the guide for integrating the equal trace segments.

The plate travel is synchronized with recording chart travel to insure that quantitative measurements of density can be produced and reproduced accurately. A precision d-c amplifier with stabilized zero and stabilized gain multiplies the minute current from the photocell to a value measurable by a self-balancing potentiometer recorder.

2) The first recorder consists of a Speedomax Type G self-balancing functioning recorder having adjustable zero, adjustable span, and a ful scale balancing speed of less than one second. This recorder indicates continuously the magnitude of the amplified photocell current and traces a graph on its chart in synchrony with the scanning unit plate travel.

A major feature of the complete assembly consists of a special d-c retransmitting slidewire mourted in this Speedomax Self-Balancing Potentiometer Recorder, with a moving contact on this slidewire driven in synchrony with the recording pen in an indicating pointer. This retransmitting slidewire is divided very precisely into 20 equal segments, each segment being shunted by an adjustable ten-turn potentiometer. An adjustable d-c voltage is impressed across the total slidewire, and the output of the slidewire is characterized by adjusting the 20 potentiometer dials to provid a calibrated output from this slidewire from the trace of the reference wedg

3) The uncorrected wedge trace on the first recorder is scaled by the operator at 20 equal intervals, using a special transparent rule

calibrated to provide direct setability of a calibration factor on the 1000 division dials of the 20 potentiometers.

Since the scale of the first recorder is determined by the per cent of transmitted light, and the calibrating retransmitting slidewire corrects the scale of the second recorder to standard wedge density, producing a straight line trace of the calibration wedge in conformity with the wedge slope, the x-ray absorption as indicated by its densitometer trace on the second recorder is related directly to the x-ray absorption of the standard wedge.

The second recorder receives, displays, and records the signal from the special calibrating retransmitting slidewire which serves as a function transformer, providing a line graph of the reference wedge and a calibrated density trace of the bone sample. Its graph also is synchronize with the automatic scanning.

Finally, a retransmitting potentiometer is driven from the output shaft of this second recorder and actuates an Instron electronic integrator which is located in the base of this unit. The integrator provides a digital readout proportional to the area under the calibrated densitometer trace of the bone section which has been scanned on the second recorder.

The TWU bone densitometric system has received further automatio by the addition of a small digital computer to the analogue system. See Figure 2.

The light transmission data from the film, in the form of a voltage functional with per cent light transmission, are measured with the same modified Knorr-Albers microphotometer as described above, except for the fact that the vacuum tube d-c amplifier originally used in the unit has been replaced with a solid-state amplifier and power supply to provide additional stability. The film is held in the motor-driven assembly that traverses a light beam as described previously. In the previous analogue system, analogue computer techniques employing adjustable function potentiometers were utilized to calibrate the light-transmission in terms of wedge-thickness for each film. Calibrated data from subsequent bone scans then were integrated by means of the electromechanical (Instron) integrator, as described. These systems required that several step-by-step adjustments and calibrations be performed by an operator.

In the new assembly, the output of the scanning unit is connected through an amplifier (Astrodata Model 885) to a small digital computer (a Digital Equipment Computation PDP-8 supplied by Kaman Company). An illustration of the system is shown in Figure 3. An analogue-to-digital (A/D) converter formats the data for direct processing by the computer, and the computer samples the data at specific intervals of time. Programming and operating control is effected through a teletypewriter unit (TTY) that includes a paper-type input/output (I/O) feature.

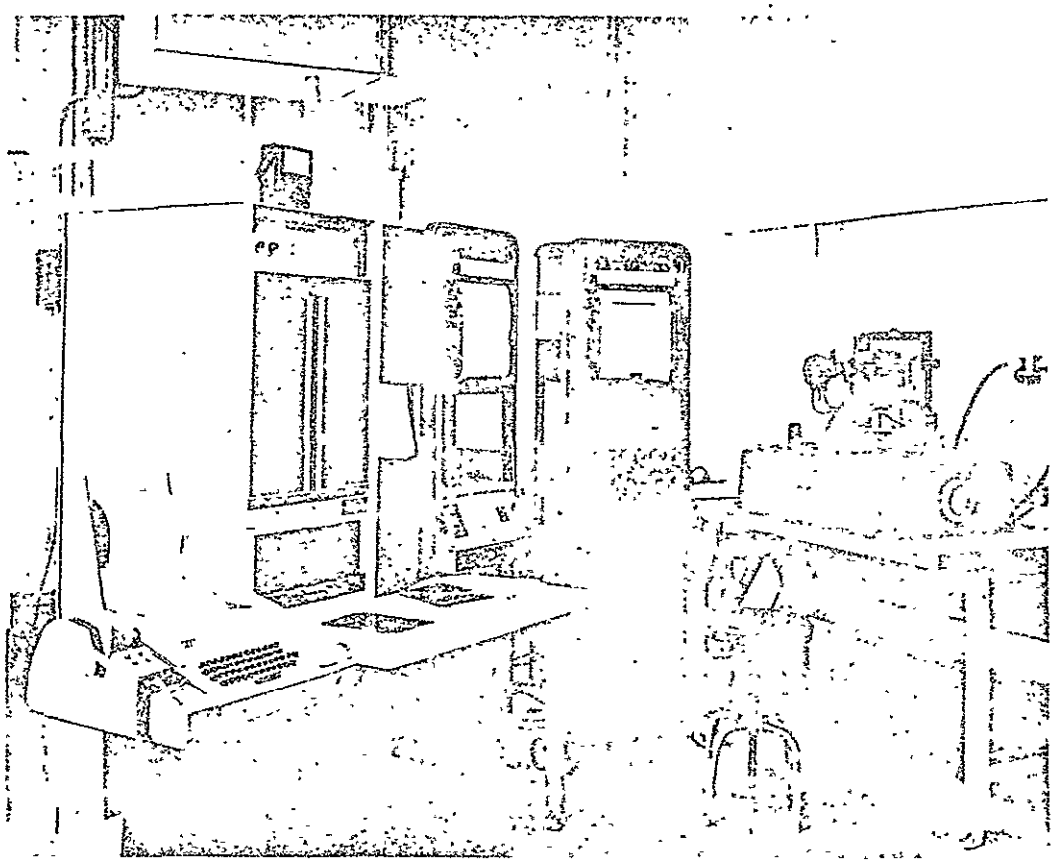

Figure 2. Photograph showing the microphotometer and digital computer system. (A) Densitometer involving the analog system developed at the Texas Woman's University. (B) Transmitting recorder for tracing calibration wedge (upper), and potentiometers for correcting calibration wedge trace. (C) Recording potentiometer for scanning corrected wedge trace as well as the traces of bone scans. (D) Digital computer which has replaced the manual operations involved in B and C of the analog system.

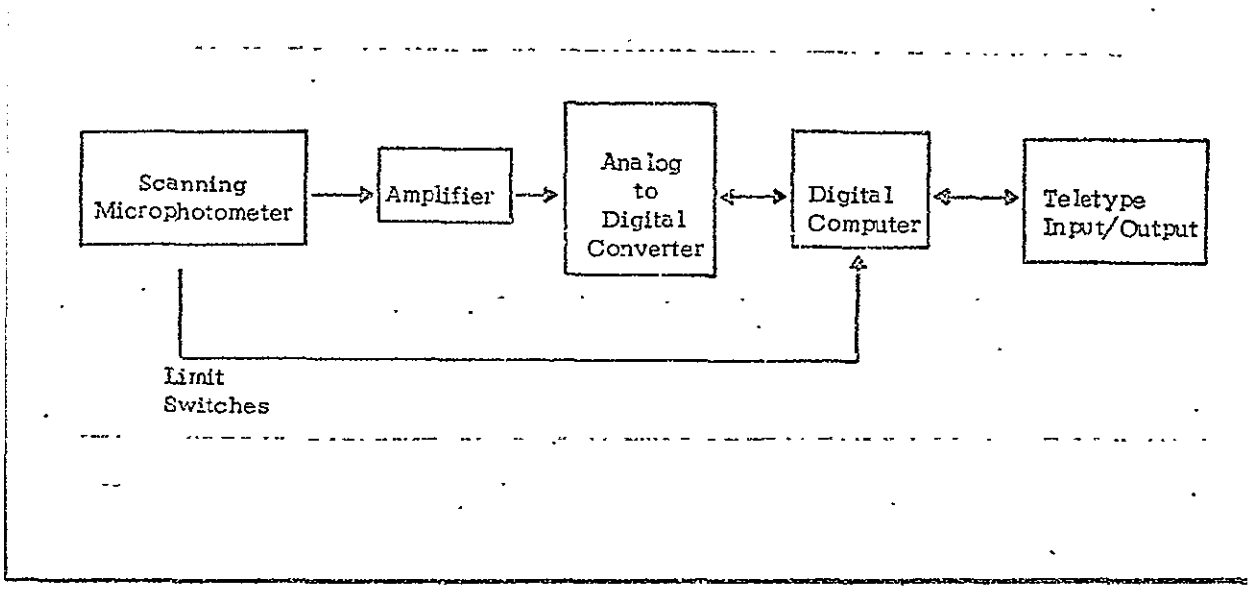

Figure 3. Block Diagram of Microphotometer Computer Assembly, from Vogt, F. B., Meharg, L. S., and Mack, P. B., The American Journal of Roentgenology, Radium Therapy and Nuclear Medicine, Volume CV, Number 4, April 1969, page 872.

The computer has been implemented to perform computations similar to the functions performed by the previous analogue system. First, the wedge image is scanned and the resulting light transmission data are stored in terms of distance along (or thickness of) the wedge. Second, the bone image is scanned and the resulting light transmission data are stored. After both the wedge and bone scans have been completed, the computer calibrates the stored bone scan data in terms of equivalent wedge thickness by using the stored wedge scan data. The calibrated bone data then are integrated along the scan by using a trapezodial approximation integration formula.

The present system offers an advantage over the earlier system in providing an automatic means for calibrating the film in terms of the light transmission of the aluminum wedge, the roentgenogram of which is taken simultaneously with the roentgenogram of the bone of interest. Earlier systems required manual operations by the operator to analyze the film. In the new system, manual operations required of the operator have been reduced to those involving the scan of the film. The accuracy and reproducibility of the technique are limited primarily upon operator care in setting up the film for scanning, selection of the scan path, and precise adjustment of the scan limits to activate the start and stop of computation by the digital computer.

The previous system has been evaluated in considerable detail. The present technique also has been evaluated to show the reproducibility of successive scans. The results have been compared with the output of the analogue system with the finding that the analogue and digital systems provide essentially the same results. The digital technique, however, offers a more rapid procedure for analyzing the films, and it reduces the technical error that can be introduced by the operator in measuring the heights of the uncorrected initial wedge trace at 20 points and adjusting the corresponding potentiometers.

X-RAYS OF BED REST SUBJECTS

Radiographs were made of the left foot in lateral aspect, and of the left hand in anterior-posterior view as in the case of the astronauts. The sections scanned on the x-rays were the following:

(a). Two preliminary scans on the foot, one of the central section of the os calcis and one of the central section of the talus. See Figure 4.

(b) Multiple sections of the os calcis, consisting of scans the width of the scanning beam, covering approximately 60 per cent of the os calcis or large heel bone, in parts where there is no overlapping of other bones were scanned. Usually 41-44 scans are required to cover this area of

the heel bone in a mature man, depending on the size of the foot. See Figure 5.

(c). The following sections of the hand and wrist are scanned (See Figure 6).

(1) Hand phalanx 4/2 (about 17 to 19 sections are scanned);

(2) Hand phalanx 5/2 (about 24 to 28 sections are scanned);

(3) One scan across the capitate, a wrist carpal; and

(4) One scan each across the distal ends of the radius and of the ulna.

Therefore, from 87 to 96 sections in the hand and foot are measured for bone density in an adult male, giving results for the various types of bone from lacy trabecular to dense cortical skeletal tissue.

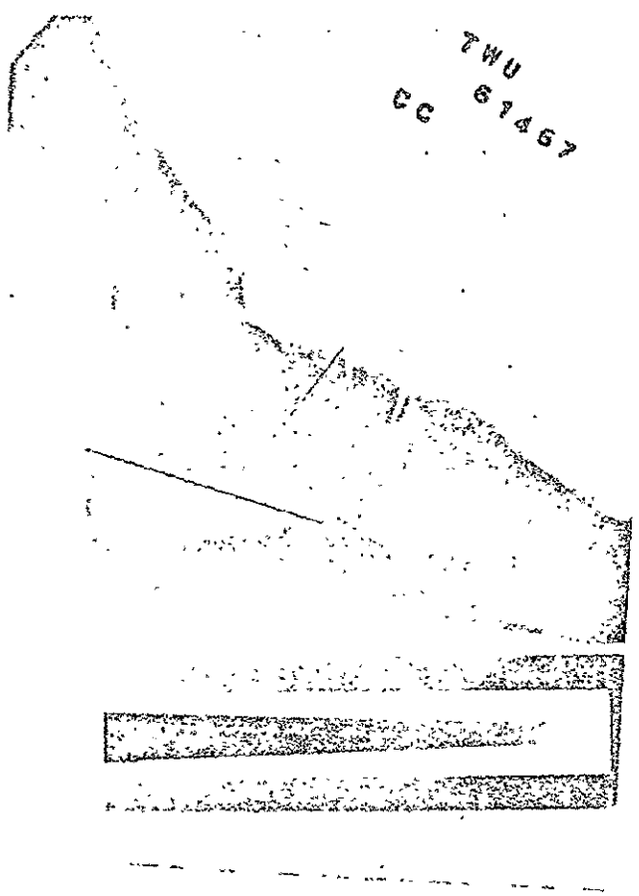

Figure 4. Lateral roentgenogram of the foot, indicating the "conventional" scanning path of the central os calcis and of the talus.

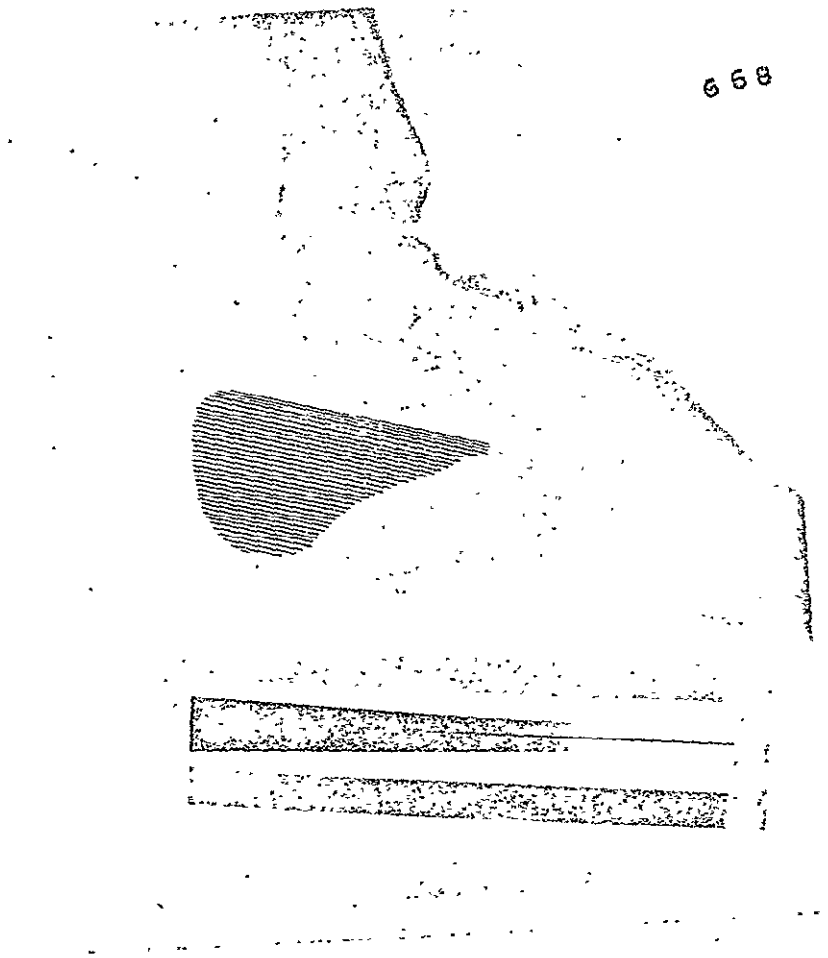

Figure 5. Roentgenogram of the foot in lateral projection showing the alignment of parallel scans covering approximately 60 per cent of the os calcis.

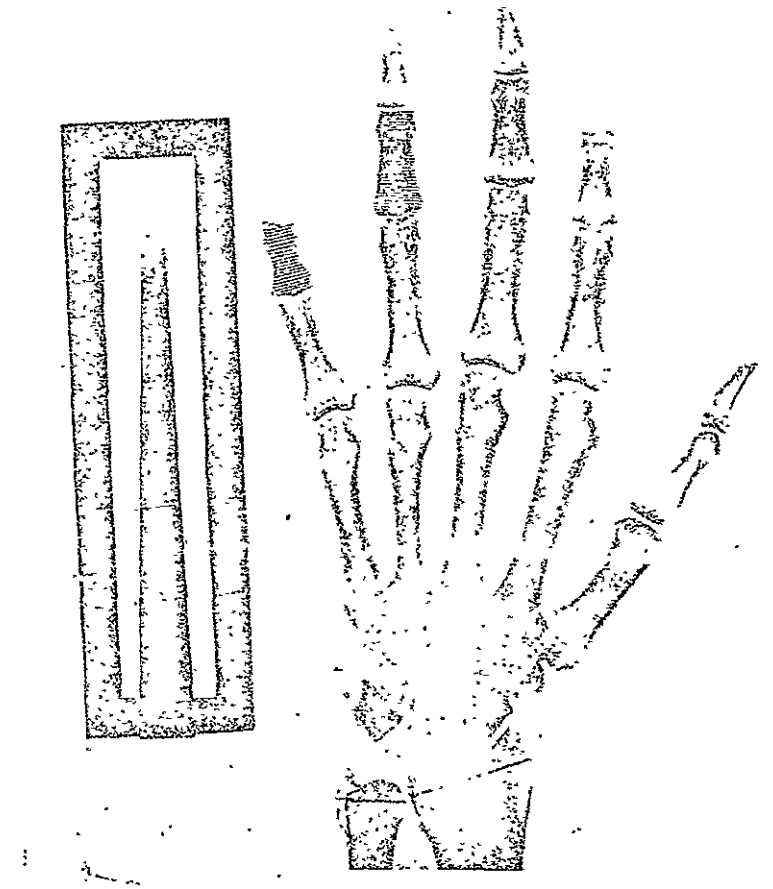

Figure 6. Roentgenogram of the hand in postero-anterior projection, indicating parallel scans which cover hand phalanges 4/2 and 5/2.